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TALC IN WHITEWARE*

By R. F. Geller and A. S. Creamer

Abstract

Three talcs, representative of low, medium, and high CaO content, were used in preparing twenty-four bodies which were heated at four temperatures. The products ranged from the highly porous earthenware type to porcelain, and test results indicate some possibilities and limitations which the whiteware industry may expect of whiteware bodies made with 14 to 40% talc.

I. Introduction

In recent years talc, as an ingredient of ceramic whiteware, has received the renewed interest of technicians and producers both in this country and abroad. Talc will act as a flux, reducing the amount of feldspar necessary to produce the desired strength and structure and will decrease materially the moisture expansion of porous bodies and consequent crazing of the glaze. Since it enhances the fluxing effect of feldspar, nonporous ware may be produced at lower temperatures and, by reducing thermal expansion, it increases resistance to thermal shock. Talc, however, also decreases the viscosity of the feldspathic interstitial glass and shortens the temperature range in which feldspar changes from a state of incipient fusion to that of a comparatively fluid glass. Therefore, a body containing talc in amounts under approximately 40% has been found to "underfire" or "overfire" easily and to warp. In order to overcome these manufacturing difficulties and enable the producer to avail himself of the advantages resulting from the use of talc, the National Bureau of Standards undertook an investigation of the effects of different talcs in whiteware and of the properties of compositions in which feldspar and talc were varied systematically. The present report covers the third study of this investigation.

The first study[1] was limited to mixtures containing from 0 to 14.4% MgO and 72.0 to 74.8% SiO_2 and was of primary interest to producers of wall tile. The second study[2] was more fundamental in character, dealing with the thermal decomposition of talc, *i.e.*, the final products resulting from the heating of a pure mineral talc. This, the third study, was conducted for the purpose of developing ceramic whiteware bodies (not limited to tile) containing talc, which could be adapted by the industry in the production of ware by more economical methods and of improved quality.

II. Materials Used

The ball clay (Kentucky No. 4), kaolin (Georgia "soft"), potash feldspar, and potter's "flint" (crushed quartz) were portions of the same materials used in the first study and also in an earlier investigation,[3] the report of which gives their chemical compositions. The ball clay was washed through a No. 200 sieve, dried, and crushed to pass a No. 8 sieve before using. The kaolin, feldspar, and flint were used as received from the producers.

Three talcs were used, as received, and their chemical compositions are given in Table I. The compositions of talcs A and C are taken from the report of the first study, and the composition of talc B was determined, having been obtained especially for this study. Talc A, used in bodies 1 to 8 inclusive, is of the tremolitic type, fibrous, and of relatively high lime content. Talc B, in bodies 9 to 16 inclusive, is composed essentially of mineral talc and is of intermediate lime content. Talc C, in bodies 17 to 24 inclusive, is a commer-

Table I

Chemical Composition of Talcs Used

No.	Source	Used in bodies	MgO (%)	CaO (%)	SiO_2 (%)	Ignition loss (%)	R_2O_3 (%)
A	New York	1–8 inc.	30.5	6.9	55.9	5.4	1.3
B	California	9–16 "	30.5	1.6	59.7	7.0	1.2
C	"	17–24 "	31.7	0.3	61.4	5.4	1.2

* Publication approved by the Director of the National Bureau of Standards of the U. S. Department of Commerce. Received November 17, 1936.

[1] R. F. Geller and A. S. Creamer, "Talc in Whiteware Bodies of the Wall-Tile Type," *Jour. Amer. Ceram. Soc.*, **18** [9] 259–69 (1935).

[2] R. H. Ewell, E. N. Bunting, and R. F. Geller, "Thermal Decomposition of Talc," *Jour. Research Nat. Bur. Stand.*, **15** [5] 551–56 (1936); R. P. 848; *Ceram. Abs.*, **15** [2] 76 (1936).

[3] R. F. Geller, D. N. Evans, and A. S. Creamer, "Effects of Particle Size of a Potter's 'Flint' and a Feldspar in Whiteware," *Bur. Stand. Jour. Research*, **11** [3] 327–40 (1933); R. P. 594; *Ceram. Abs.*, **12** [12] 427 (1933).

cially pure mineral talc, nearly lime-free, and is probably from the same source as that used by Fallon.[4]

The content of lime was taken as the basis for classification of the three talcs because of the marked influence lime exerts on the behavior of a whiteware body, as was shown in the first study and corroborated by Hagar.[5]

III. Bodies

The bodies (Table II) were formulated according to the scheme shown in Fig. 1, using the calculated chemical compositions of the heated mixtures as a basis. Bodies 1 to 4, inclusive, lie in the plane of the MgO–Al_2O_3–SiO_2 system; bodies 5 to 12, inclusive, and 17 to 20, inclusive, contain 1.5% K_2O and Na_2O (introduced as feldspar) in addition to the 3 oxides indicated in the figure. Bodies 13 to 16, inclusive, and 21 to 24, inclusive, contain 3.0% K_2O and Na_2O in addition to the three principal oxides. This scheme of formulation necessitated disregarding Fe_2O_3, TiO_2, and other minor constituents present as impurities. For those bodies containing significant quantities of CaO (1 to 16, inclusive), the CaO was also considered to replace MgO. The purpose of this scheme was to obtain a wide range in behavior during heating with a minimum number of bodies.

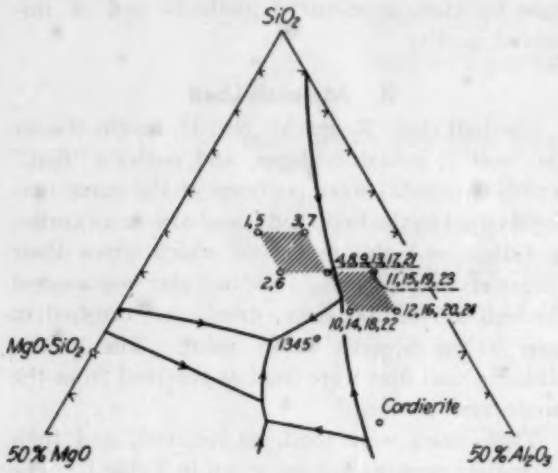

FIG. 1.—Anhydrous body compositions. Although plotted in the MgO–Al_2O_3–SiO_2 ternary diagram the indicated percentage of MgO represents combined MgO and CaO in the bodies, their relative proportions being given in Table II; the numbers at the points of the shaded areas refer to the compositions in the table. In all bodies, 7% of the Al_2O_3 is introduced as ball clay. All bodies except 1 to 4 inclusive also contain 1.5 or 3.0% $K_2O(Na_2O)$ introduced as feldspar, in addition to the indicated percentages of $Mg(Ca)O$, Al_2O_3, and SiO_2.

Since the series of body compositions was devised according to chemical composition, it was necessary to calculate batch weights without consideration of such factors as workability, shrinkage, etc. Each batch composition, however, was calculated to introduce 7% Al_2O_3 as ball clay, thus insuring that no composition would be unworkable and that the content of the most plastic ingredient would be maintained at a fairly constant value.

A reference body was prepared and tested with the "talc bodies." It was made of 8% feldspar, 25% ball clay, 30% kaolin, and 37% flint. This composition typifies commercial wall tile and is identical with the reference body (B) of the first study, except that the flint and feldspar had not been reground but were used as received.

IV. Methods

(1) Preparation of Specimens

Twenty-five pounds of each body were ground wet in ball mills for three hours, passed through a No. 100 sieve and over a magnetic separator, filter-pressed, and stored damp for at least two weeks. One portion was then extruded to form solid rods $^5/_8$ inch in diameter by 6 inches long. Another portion was dried, crushed to pass a No. 30 sieve, mixed thoroughly with 10% of water, passed through Nos. 12 and 30 sieves successively, and pressed into rods, $6^1/_4$ inches long, of rectangular cross-sections measuring $^3/_{16}$ by $^3/_4$ inch, using a pressure equivalent to 100 kilogram per square centimeter.

All specimens were heated to at least three of the following temperatures, in degrees centigrade; 1145° (cone 4), 1175° (cone 6), 1220° (cone 8), and 1255° (cone 10). They were suspended in a direct gas fired kiln, the pressed bars being placed next to corresponding extruded bars in order that possible differences caused by the methods of forming would not be affected by differences in heat treatment.

(2) Linear Shrinkage

Linear shrinkage of extruded bars was measured directly by using a caliper. Shrinkage of pressed bars was measured in an especially de-

[4] F. F. Fallon, "A Study of Some Ceramic Bodies Containing Talc," *Jour. Amer. Ceram. Soc.*, **18** [7] 199–201 (1935).

[5] Donald Hagar, "Effect of a Tremolitic Talc in Whiteware Bodies," *ibid.*, **19** [1] 14–23 (1936).

signed holder, using an Ames gage reading to 0.001 inch. Values are expressed in percentages of the initial "green" lengths.

(3) Water Absorptivity

Water absorption was calculated from the weight of a dry specimen and from the weight after having been "autoclaved" for 5 hours at a steam pressure of 150 pounds per square inch while immersed in water.

(4) Moisture Expansion

Moisture expansion was determined only on dry-pressed specimens. Calculations are based on measurements made before and after the autoclave treatment used in the test for absorptivity and are expressed in percentage of the over-all length measured with the 0.001-inch (0.0254 millimeter) Ames gage before autoclaving. The differential length (or expansion during autoclaving) was taken as the difference in readings on a 0.01-millimeter (0.00039-inch) gage. These readings were made in a room maintained at 70 ± 2°F and 60 ± 5% relative humidity, and the specimens had been in this room at least overnight before the readings. Since the over-all lengths (approximately 6 inches or 152.4 millimeters) could be read to 0.001 inch (0.0254 millimeter), and the differential readings could be estimated to ± 0.001 millimeter (0.000039 inch), the values for moisture expansion are estimated to be within ± 0.0015.

(5) Moduli of Elasticity and Rupture

Young's modulus of elasticity of extruded bars was calculated from values determined with a device described by Kessler and Sligh[6]; calculations for pressed bars are based on deflections obtained by direct loading, using a simple apparatus designed for the purpose. Pressed bars were broken on this same apparatus for determination of modulus of rupture, but the extruded bars were broken with the machine described by Harrison.[7]

(6) Extensibility

By extensibility is meant the computed maximum outer fiber strain, which is calculated by dividing the modulus of rupture by Young's modulus of elasticity.

TABLE II

BODY COMPOSITIONS

Body	Batch weights (%)					Approx. chemical (%)				
	Talc	Feldspar	Ball clay	China clay	Flint	CaO	MgO	R_2O*	Al_2O_3	SiO_2
1	37.4		21.7	6.2	34.7	2.8	12.2		10	75
2	36.8		21.4	17.6	24.2	2.8	12.2		15	70
3	24.7		21.5	17.9	35.9	1.8	8.2		15	75
4	24.3		21.2	29.0	25.5	1.8	8.2		20	70
5	37.0	9.0	21.5	2.0	30.5	2.8	12.2	1.5	10	75
6	36.5	9.0	21.2	13.3	20.0	2.8	12.2	1.5	15	70
7	24.5	8.9	21.3	13.6	31.7	1.8	8.2	1.5	15	75
8	24.1	8.8	21.0	24.7	21.4	1.8	8.2	1.5	20	70
9	28.4	8.8	21.0	24.9	16.9	0.5	9.5	1.5	20	70
10	28.0	8.6	20.7	35.7	7.0	.5	9.5	1.5	25	65
11	14.2	8.7	20.8	36.1	20.2	.3	4.7	1.5	25	70
12	13.9	8.6	20.5	46.6	10.4	.2	4.8	1.5	30	65
13	28.2	17.5	20.8	20.7	12.8	.5	9.5	3.0	20	70
14	27.8	17.2	20.5	31.4	3.1	.5	9.5	3.0	25	65
15	14.0	17.3	20.6	31.8	16.3	.3	4.7	3.0	25	70
16	13.8	17.0	20.3	42.3	6.6	.2	4.8	3.0	30	65
17	Batches same as in bodies 9 to 16, incl.					Tr.	10	1.5	20	70
18						"	10	1.5	25	65
19						"	5	1.5	25	70
20						"	5	1.5	30	65
21						"	10	3.0	20	70
22						"	10	3.0	25	65
23						"	5	3.0	25	70
24						"	5	3.0	30	65

* Principally K_2O.

[6] D. W. Kessler and W. H. Sligh, "Physical Properties of Limestones Used for Building in the U. S.," *Bur. Stand. Tech. Paper*, No. 349 (Vol. 21, p. 497) (July, 1927); *Ceram. Abs.*, **7** [5] 326–27 (1928).

[7] A. C. Harrison, "A Machine for Transverse Tests of Clay and Glass Laboratory Specimens," *Jour. Amer. Ceram. Soc.*, **8** [11] 774 (1925).

TABLE III

VALUES FOR THE REFERENCE BODY (COMPOSITION TYPICAL OF COMMERCIAL WALL TILE)

Heated at (°C)*	Water absorptivity (%)	Total linear shrinkage (%)	Moisture expansion (%)	Linear thermal expansion room temp. to 700°C (%)	(*E*) Young's modulus of elasticity (lb./sq. in.)†	(*R*) Modulus of rupture in bending (lb./sq. in.)‡	Extensibility *R/E* (%)
			Extruded				
1175	15.4	7.9			3.1	3.7	0.12
1220	13.3	8.2		0.58	3.4	4.6	.14
1255	12.0	8.9		0.63	4.5	4.5	.10
			Pressed				
1175	15.1	3.5	0.12		1.8	1.7	0.07
1220	13.1	4.4	.11		2.6	2.4	.09
1255	12.4	4.7	.12		3.0	2.7	.09

* Cones 6, 8, and 10, respectively.
† $\times 10^6$.
‡ $\times 10^3$.

TABLE IV

SOME PROPERTIES OF AND COMMENTS REGARDING THE EXTRUDED BODIES*

Body	Shrinkage during drying (%)	Water of plasticity (%)	Remarks regarding workability	Color of specimens heated at 1220°C (cone 8)
Ref.	4.3	26	Extruded well and produced firm specimen	Good white
1	4.3	27	Poor workability	Light ivory
2	4.2	28	Somewhat less workable than reference body	" "
3	3.7	26	Somewhat less workable than reference body	" "
4	3.8	27	Extruded about same as body 8	" "
5	3.6	25	Better than body 1; good workability considering low clay content but very difficult to jigger	" "
6	4.0	26	Poor workability	Light gray
7	3.7	25	" "	" "
8	4.0	27	Extruded fairly well; jiggered very well	" "
9	4.5	29	Better than body 1 but definitely less workable than body 8	Light grayish buff
10	4.3	29	Compares favorably with reference body	" " "
11	3.6	28	Increasingly difficult to work, No. 13 being about the same as body 9	" " "
12	4.1	29		" " "
13	4.5	29		Gray
14	4.5	29	Workability almost as good as bodies 2 and 3	"
15	4.1	28	Workability almost as good as bodies 2 and 3	"
16	4.2	29	Workability almost as good as bodies 2 and 3	"
17	4.5	27	About same as body 5	Light grayish buff
18	4.8	29	" " " " "	" " "
19	4.3	29	Somewhat better than bodies 11, 12, and 13, respectively	" " "
20	3.9	29		" " "
21	4.2	27		Gray
22	4.1	28	Compares favorably with bodies 2 and 3	"
23	4.0	27	" " " " " " "	"
24	4.0	29	" " " " " " "	"

* All bodies pressed satisfactorily when prepared with 10% water and the shrinkage during drying was not determined.

(7) Linear Thermal Expansion

Data for linear thermal expansion were obtained by E. N. Bunting and calculated from determinations by the interferometer method, using appropriate specimens formed by plastic molding.

V. Results

Results are summarized in Tables III, IV, and V and in Figs. 2, 3, 4, and 5. Values for shrinkage during drying are the average of 20 determinations. Values for total shrinkage, water absorptivity, moisture expansion, and modulus of rupture are the average of ten determinations. Young's modulus of elasticity was calctulated from data for at least three specimens, and the linear thermal expansion was calculated from results for one specimen, except when comparison with results for other specimens of a series indicated the desirability of duplicate tests.

All of the values for moduli of rupture and elasticity plotted in Figs. 2, 3, and 4 are for specimens which had been previously autoclaved as part of the tests for absorptivity and moisture

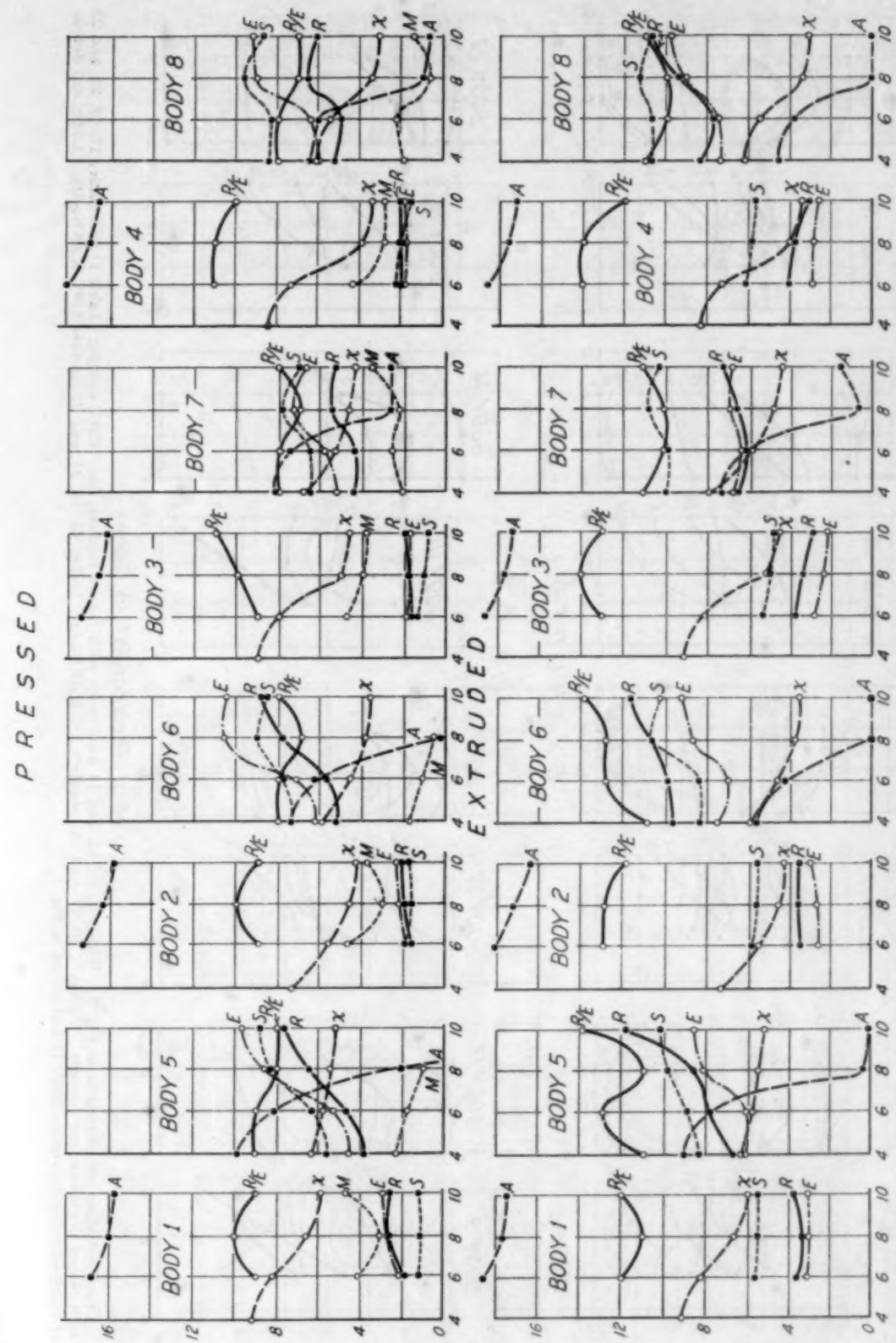

FIG. 2.—Shows values for the 8 compositions (Table II) made with "high-lime talc" (Table I). All values are plotted on one numerical scale but in different powers of 10 and the letters accompanying the curves signify the following: (*A*) absorptivity in parts per 100; (*R*/*E*) extensibility in parts per 10,000; (*R*) modulus of rupture in 1000 lb. per sq. in.; (*E*) Young's modulus of elasticity in 1,000,000 lb. per sq. in.; (*M*) moisture expansion in parts per 10,000: (*S*) total shrinkage in parts per 100; and (*X*) linear thermal expansion from room temperature to 700°C in parts per 1000. For example, values for body 2 pressed and heated at cone 8 are absorptivity (*A*) 0.164 or 16.4%, extensibility (*R*/*E*) 0.0010 or 0.10%, modulus of rupture (*R*) 2100 lb. per sq. in., Young's modulus of elasticity (*E*) 2,200,000 lb. per sq. in., moisture expansion (*M*) 0.00031 or 0.031%, total linear shrinkage (*S*) 0.017 or 1.7%, and, linear thermal expansion (*X*) 0.0046 or 0.46%.

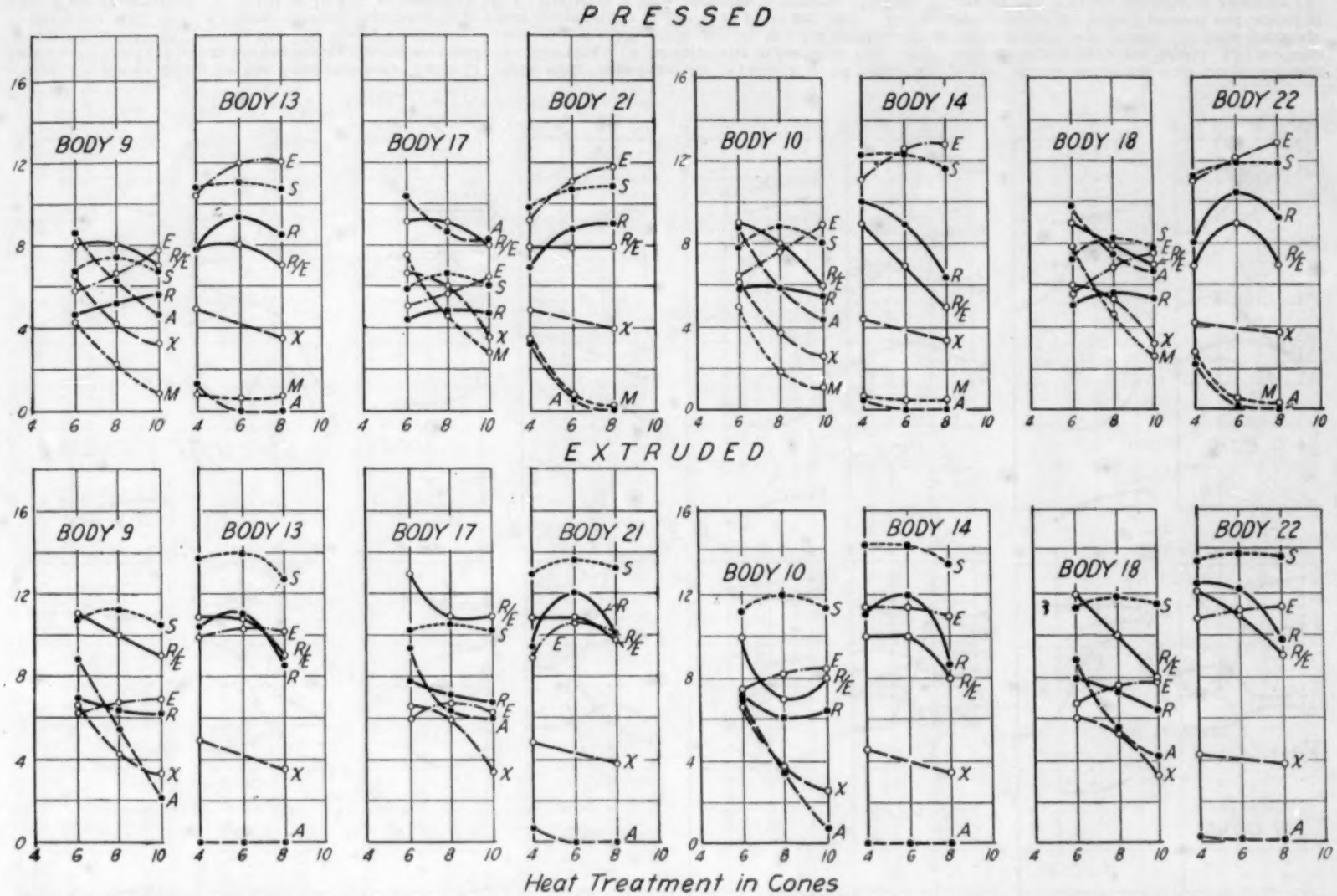

FIG. 3.—Values are plotted as in Fig. 2. Bodies 9, 10, 13, and 14 were made with talc of medium lime (CaO) content (Table I) and bodies 17, 18, 21, and 22 with talc of negligible lime content. Bodies 9, 10, 17, and 18 contain 1.5% $K_2O(Na_2O)$; bodies 13, 14, 21, and 22 contain 3.0% $K_2O(Na_2O)$. Additional details of composition are given in Table II and shown in Fig. 1.

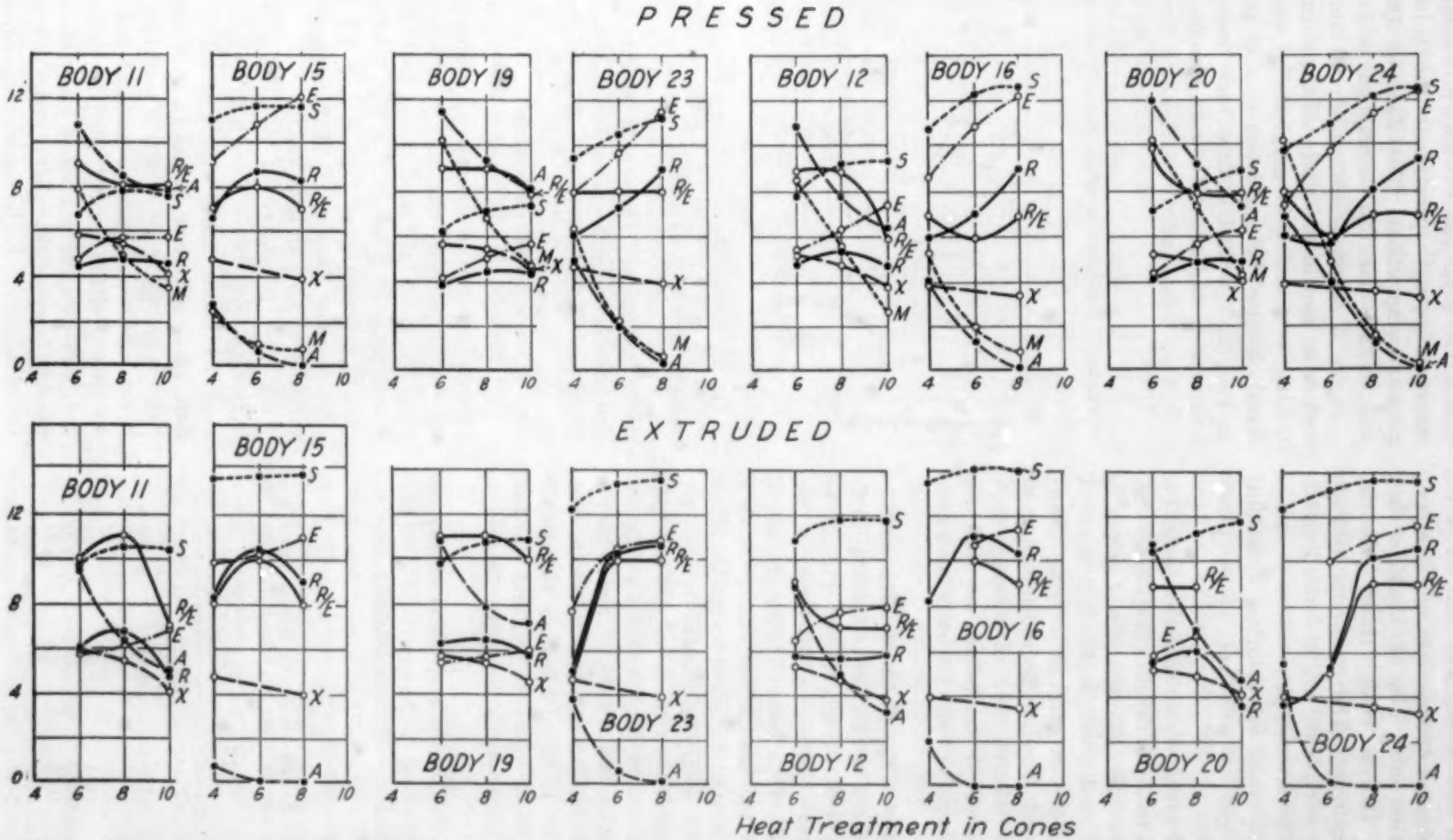

FIG. 4.—Values are plotted as in Fig. 2. Bodies 11, 12, 15, and 16 were made with talc of medium lime (CaO) content (Table I), and bodies 19, 20, 23, and 24 with talc of negligible lime content. Bodies 11, 12, 19, and 20 contain 1.5% $K_2O(Na_2O)$; bodies 15, 16, 23, and 24 contain 3.0% $K_2O(Na_2O)$. Additional details of composition are given in Table II and shown in Fig. 1.

expansion. It will be observed that all of the data for the heated specimens of any one body are plotted in one subdivision or "block" of these figures. The data in Table III are presented only for comparison. The comments in Table IV regarding workability are of limited significance because no attempt was made to determine proper water content for optimum workability except as judged by the "feel" of the plastic bodies.

Figure 2 shows the plotted values for bodies 1 to 8, inclusive, made with the "high-lime" talc from New York State. Comparison of graphs for bodies 5, 6, 7, and 8 with bodies 1, 2, 3, and 4, respectively, shows the effect of 1.5% $K_2O(Na_2O)$ introduced as feldspar into bodies containing no feldspar. The relative effect of pressing *vs.* extruding is shown by comparing any block of graphs in the upper tier with the block immediately beneath.

In Figs. 3 and 4, the effects of three variables may be considered in addition to the $Mg(Ca)O$–Al_2O_3–SiO_2 contents (Fig. 1). In Fig. 3, for example, bodies 9, 13, 10, and 14 contain a "medium-lime" talc, while bodies 17, 21, 18, and 22 contain a talc practically "lime-free"; bodies 9, 10, 12, and 18 contain 1.5% and bodies 13, 14, 21, and 22 contain 30% $K_2O(Na_2O)$, respectively. The four bodies in any right or left half of Figs. 3 and 4 have the same $Mg(Ca)O$–Al_2O_3–SiO_2 content. In addition, bodies 9, 13, 17, and 21 may be compared with bodies 4 and 8, as is evident from Fig. 1 and Table II, in order to study the effect of varying $K_2O(Na_2O)$ from 0 to 3%, and the CaO (replacing MgO) from a negligible amount to 1.8%.

Values for the thermal expansion of any one body are plotted both in the upper and lower tiers (Figs. 2, 3, and 4). It was assumed that the values for expansion of the "plastic molded" specimens would approximate the values for pressed compositions. The data in Table V indicate how far this assumption is justified.

Figure 5 shows the effect of the autoclave treatment used in this study on the strength in bending. A total of 97 unautoclaved specimens remained after the completion of tests reported in Figs. 2, 3, and 4. These were broken and compared with data for 108 corresponding autoclaved specimens. The results indicate strongly that autoclaving will weaken bodies of both relatively low and relatively high absorptivity.

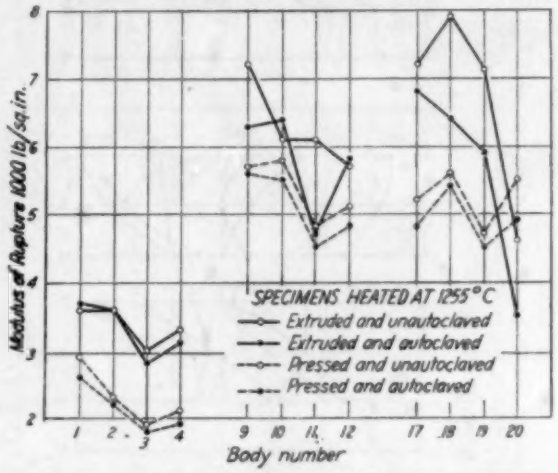

FIG. 5.—Showing the effect of autoclaving at 150 lb. per sq. in. steam pressure for 5 hours on strength in bending (modulus of rupture).

TABLE V

LINEAR THERMAL EXPANSION OF SIX BODIES FORMED BY PRESSING AND BY MOLDING WHILE PLASTIC

Body	Heated at °C	Expansion from room temp. to 700° of specimens: Molded (%)	Expansion from room temp. to 700° of specimens: Pressed (%)
Ref.	1255	0.66	0.63
1	1255	.63	.59
10	1220	.37	.42
10	1255	.26	.26
11	1220	.54	.56
11	1255	.41	.40
17	1220	.60	.59
18	1220	.58	.58

VI. Discussion

(1) Feldspar is the constituent having the greatest influence on absorptivity, shrinkage, and the accompanying changes in strength and elasticity which take place during heating. This is demonstrated graphically in Fig. 6, although a cursory examination of Figs. 2, 3, and 4 is sufficient to show the marked changes caused by a variation of 1.5% in $K_2O(Na_2O)$.

(2) The possibility of developing vitrified bodies maturing below cones 8 to 10 appears remote for bodies made with a so-called "high-lime talc." Of these bodies (1 to 8 inclusive), No. 5 is promising for a cone 5 wall tile, bodies 7 and 8 for cone 5 earthenware, and body 8 also for cone 9 vitrified ware. Body 8, when vitrified, would require a glaze of lower thermal expansion, however, than that of glazes now common to the industry. No bodies in this group, further-

more, would be suitable for plants operating kilns at cones 6 to 8. The abrupt drop in absorptivity of bodies 5, 6, 7, and 8 is probably caused by the lime decreasing the viscosity of the molten feldspar[8] and increasing the "fusibility."[9]

(3) Bodies 9 to 12 and 17 to 20, inclusive, containing 1.5 % $K_2O(Na_2O)$ and made with talc of 1.6% or less CaO content, did not vitrify at or below cone 10. The introduction of 3.0 % alkali oxides (bodies 13 to 16 and 21 to 24, inclusive) produced vitrification in some compositions when

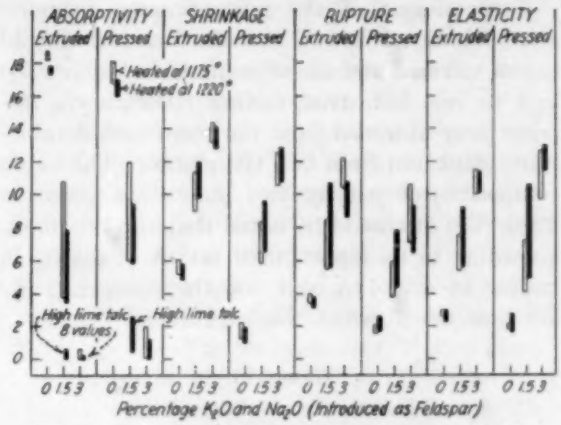

FIG. 6.—Effect of K_2O and Na_2O, introduced in the batch mixtures as feldspar (Table II), on the absorptivity and total linear shrinkage (values in percentage), strength in bending (modulus of rupture in 10^3 lb. per sq. in.) and elasticity (Young's modulus in 10^6 lb. per sq. in.). Each hollow column covers the range of values for all bodies of the indicated $K_2O(Na_2O)$ content heated at 1175°C (cone 6) and the filled columns cover the range of values for all bodies heated at 1220°C (cone 8). Wherever "overlapping" of group values occurred (*e.g.*, rupture values of bodies heated at 1220°C and containing 1.5 and 3.0% $K_2O(Na_2O)$, it was caused by bodies 5 to 8, inclusive, which contain the "high-lime talc."

heated to not over cone 4. Bodies 13, 14, and 22 are suggested for trial in manufacturing cone 5 vitrified products, body 17 for cone 9 wall tile, and body 24 for cone 9 vitrified products. It must be considered, however, that the "low and medium lime talcs" now available are relatively expensive in eastern markets and that a material lowering in thermal expansion accompanies lowering of absorptivity. The latter should be advantageous but will require development of glazes of suitable thermal expansion.

(4) In no case did a composition have a maturing range of more than two cones. This should suffice, however, for modern kilns equipped with automatic temperature control.

(5) When dealing with bodies containing talc, a decrease in mechanical strength with increased heating is not a definite indication that a composition is "overfired," nor is maximum strength a criterion of optimum heat treatment. Bodies 5 and 6, heated to cone 10, for example, were badly deformed at the point of suspension because of softening, but the strength in bending (modulus of rupture) had not been impaired. On the other hand, extruded bodies 13, 14, 21, and 22, when heated to cone 8, had decreased markedly in strength, as compared with specimens from the cone 6 heating, but showed only slight deformations and no vesicular structure.

It is suggested that decrease in strength may result from the development of a comparatively coarsely crystalline matrix of cordierite,[10] and the accompanying decrease in shrinkage may be caused by a lowering of the true specific gravity[11] rather than by vesicular structure.

(6) Graphs in Fig. 6 show that absorptivity, shrinkage, mechanical strength, and elasticity are interrelated. That this is true of the first three properties is common knowledge, but it is not so generally known that a relation may exist also with elasticity. This has been noted by other investigators[12] with respect to elasticity and absorptivity, which relation for bodies heated at 1175°C (cone 6) is shown by the graphs in Fig. 7.

VII. Applications

(1) Laboratory

Body compositions 5, 14, and 16 were pressed to make regular $2^3/_{16}$-inch square tile and, in addition, standard-size butter plates were pressed, using bodies 14 and 16. The bisque heat was 1150°C (cones 4 to 5).

[8] (*a*) R. Rieke and Liselotte Mauve, "Softening of Feldspar Glass and the Influence of Different Additions Thereon," *Ber. deut. keram. Ges.*, **12** [8] 379–400 (1931); *Ceram. Abs.*, **11** [3] 188–89 (1932).
(*b*) W. M. Cohn, "Viscosity Measurements in Feldspar Melts at High Temperatures," *Ber. deut. keram. Ges.*, **15** [11] 551–58 (1934); *Ceram. Abs.*, **14** [6] 152 (1935).

[9] Edward Schramm and F. P. Hall, "The Fluxing Effect of Feldspar in Whiteware Bodies," *Jour. Amer. Ceram. Soc.*, **19** [6] 159–68 (1936).

[10] A coarsely crystalline structure impairs mechanical strength. See E. Rishkevich, "Single-Phase Systems as the Basis of Scientific Ceramic Research," *Ber. deut. keram. Ges.*, **16** [3] 111–17 (1935); *Ceram. Abs.*, **15** [1] 44 (1936).

[11] See footnote 1, p. 137.

[12] (*a*) A. V. Bleininger and G. H. Brown, "Relation between the Modulus of Elasticity and the Porosity of Burned Clay," *Trans. Amer. Ceram. Soc.*, **17**, 464–70 (1915).
(*b*) R. A. Heindl and W. L. Pendergast, "III, Progress Report on Investigation of Sagger Clays; Their Elasticity and Transverse Strength at Several Temperatures," *Jour. Amer. Ceram. Soc.*, **10** [7] 524–34 (1927).

Body 5 pressed well and the bisque (light ivory) absorbed 5.7% water. It was glazed satisfactorily at 1150°C and withstood an autoclave treatment at 150 pounds steam pressure for $1^1/_2$ and 3 hours without crazing. The glaze, normally glossy, tended to semimatness.

Body 14 pressed well and, after heating at 1150°C, was light gray, vitrified, and had the appearance of a good floor tile. It is probable that this body would be satisfactory also for low-tension insulators.

Body 16 pressed satisfactorily and was glazed with a composition of relatively low thermal expansion maturing at 975°C. The texture of the body was mottled and unsuitable in appearance for commercial use.

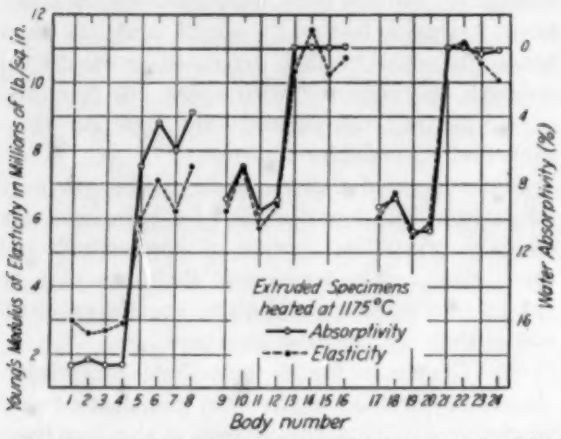

FIG. 7.—Graphs showing the relation between elasticity and absorptivity of specimens heated at 1175°C (cone 6), typical of specimens heated at the other temperatures referred to in Figs. 2, 3, and 4.

Sauce dishes and 3-inch plates were jiggered, using bodies 5, 8, 13, and 22. They were dried on open racks and bisqued at 1150°C.

Because of the low clay content, body 5 was "short" and difficult to jigger. It is probable that 2 or 3% of bentonite incorporated in the batch mix would improve the workability. The glaze, maturing at cone 4 and normally glassy, was decidedly mat but rather pleasing in appearance for artware. It withstood satisfactorily an autoclave test at 150 pounds for $1^1/_2$ hours. The absorptivity of the body was 5.7%.

Body 8 jiggered well and the same glaze used on body 5 was satisfactory in every respect. The color of the ware was an agreeable light ivory and the absorptivity of the body was 3.7%. It withstood the same autoclave treatments as given body 5 pressed.

Body 13 jiggered fairly well. The glazed specimens, although promising, were not entirely satisfactory, largely because of the shrinkage characteristics. The color was a little lighter than that of body 8.

Body 22 jiggered and glazed satisfactorily but the warpage was excessive. The body, heated at 1450°C, was vitrified.

(2) Plant

Compositions of the more promising bodies were submitted to two manufacturers of tile, to one of vitrified and one of semivitrified tableware, and to one industrial testing laboratory. Reports were obtained from the semivitrified tableware plant and from two tile plants. The batch compositions used by two plants are given in Table VI; it should be noted that the tile plant, according to its report, used talc A (Table I) in bodies 14 and 14A and not the comparatively low-lime talc B which was suggested.

TABLE VI

BATCH COMPOSITIONS OF PLANT BODIES

Body	Semivitreous*			Tile*		
	8 (%)	8A (%)	5 (%)	5 (%)	14 (%)	14A (%)
Talc A (see Table I)	24	24	37	38	28	28
Feldspar (Consolidated A2)	9	9	9			
Feldspar (Genessee)				9	17	17
Ball clay (Ky. Nos. 4 and 12)	21		21.5	22†	21†	
Peerless clay (kaolin)					31	
Cherokee clay (kaolin)	25		2			
Champion and Challenger (ball)		50				55
Flint	21	17	30.5	31	3	

* The number in the body designation is the same as the number of the experimental body used in the laboratory (see Table II).

† Ball clay No. 4 only.

The report of the plant manufacturing semivitreous ware is summarized as follows:

Bodies were formed into 7-inch plates having comparatively flat rims and both bisque- and glost-fired to "cone 5, 2 o'clock."

All bodies compared favorably with their production body on the jigger line.

The water absorption of bodies 8, 8A, and 5 was 7.08, 3.60, and 10.27%, respectively.

Shrinkage of body 5 was less and of bodies 8 and 8A greater than that of the production body.

In a quenching test of 5 cycles "from 200°C plus tap water to cool tap water," two plates of bodies 8A and five of body 8 failed, while two plates of body 5 failed and two were undamaged.

After an autoclave treatment for 3 hours at 100 pounds per square inch steam pressure, using three plates of each body, one plate of No. 8 was broken and all others were undamaged.

All bodies showed "rim drop" (*i.e.*, deformed), but body 8 appeared the best in this respect.

The report from one tile plant (Table VI) is summarized as follows:

Bodies were pressed with 12.5% water into $4^1/_4$- by $4^1/_4$- by $^3/_8$-inch tile; body 5 was bisque-fired to "cone $1^1/_8$," bodies 14 and 14A to "cone $3^1/_4$," and all were glazed at cone "$02^1/_8$."

The absorption of bodies 5 and 14 was 16.6 and 1.1%, respectively. The modulus of rupture and total shrinkage of bodies 5, 14, and 14A was 2270, 6230, and 8140 pounds per square inch and 2.3, 13.3, and 14.5%, respectively.

Body 5 was reported as straight and good white in color, bodies 14 and 14A as gray-white and badly warped. (The warpage may be explained by the use of the high-lime talc.)

The other tile plant reports that its results with a body resembling No. 5 are fairly good. Shrinkage was $2^1/_2$ to $3^1/_2$%, and glazed specimens successfully passed their autoclave test at 250 pounds per square inch for one hour, using three different types of glazes. A tendency to shivering was noted.

VIII. Summary

Among the probable advantages of talc bodies, the more important appear to be increased resistance of porous glazed ware to moisture expansion; lowered maturing temperature, especially for unglazed vitreous products formed by pressing; and increased resistance to thermal shock of vitreous bodies which, if glazed, will involve development of suitable low-temperature, low-expansion glazes. Results both in the laboratory and plant, however, indicate that any advantages to be gained by the use of talc will involve closer control of raw materials, processing, and kiln treatment than is now required for the usual feldspathic body mixtures.

Although the results of the plant trials appear to hold little promise, it must be considered that the mixtures actually used in the plants are not those which were developed in the laboratory and that the talc bodies were arbitrarily processed on a schedule not designed for them. It is now generally known in the trade that a type of semivitreous tableware, made with a body containing a medi m quantity of talc, is being marketed. It is hoped that the results reported will be of assistance in developing further both vitreous and semivitreous bodies containing talc.

THE USE OF SYENITES IN SEMIVITREOUS WARE: II, PLANT TRIALS*

By C. J. Koenig

Abstract

Five-inch plates indicating promising results were made from semivitreous bodies prepared (1) by introducing the syenite in reduced amounts and (2) by counteracting the greater fluxing action of the syenites as compared to feldspar by reducing the firing temperature. These plates passed autoclave, heat shock, impact, and chipping tests satisfactorily. When the plates embodying syenite failed after repeated tests, the failure was caused by dunting. In no case did crazing occur. Bodies in which equal parts of syenites were substituted for feldspar gave increased values for modulus of rupture and modulus of elasticity, but for the same degree of absorption the values fell within the same range. The syenite bodies showed less tendency to warpage than the feldspar body. The linear coefficient of expansion of the syenite bodies is greater than the corresponding feldspar body, and bodies combining feldspar and syenite are intermediate in this respect. Photomicrographs of body structure are included.

I. Experimental[1]

The trials described in this work were conducted with the coöperation of the Crooksville China Company and comprise bodies using two different syenites embodied in varying proportions. One body was bisque- and glost-fired at cone 4. The others were bisque-fired on the company's regular cone 9 schedule. The bisques were glazed at cone 5 with the regular glaze.

The raw materials were those used in its present dinnerware body with the exception of the vitrification agents. The chemical composition and grain size of the syenites used are given in Table I in Part I of this study.[2]

Figure 1 shows the relative tendencies for these materials to wet the porcelain test blocks. Syenite D is one of the most active syenites tested in this respect and has the highest nepheline content of the materials tested. Syenite F,[1] which has a lower nepheline content, is considerably less active as to this property.

II. Body Compositions

Body 9: Flux content (syenite C) reduced to 65% of present feldspar content, the difference being replaced by flint.

Body 10: Flux content (syenite F) reduced to 95% of present feldspar content, the difference being replaced by flint.

Table I

Physical Properties of Some Bodies Containing Syenite and Feldspar, Respectively

Body No.	9 Syenite C	10 Syenite F	11 Potash feldspar	12 Potash feldspar	13 Syenite F	14 Syenite C
Ratio to normal flux content (1)	0.65	0.95	1	1	0.95	1.13
Linear firing shrinkage (%)	2.8	3.0		3.4	3.2	3.1
Total linear shrinkage (%)	6.1	6.86	8.2	7.6	7.4	7.3
Absorption (plates) (%) cone 4	8.5	7.4	7.3	7.6	7.2	8.9
Absorption (plates) (%) cone 9						1.2
Absorption (bars) (%)	7.6	6.0		7.2	6.5	7.9
Fired strength modulus (lb./sq. in.)	3900	3980		4280	4680	4560
Modulus of elasticity (million lb./sq. in.)	5.26	4.86	5.20	5.21	5.00	5.45

Body 11: Regular Crooksville 5-inch plates selected from run-of-kiln when bodies 9 and 10 were prepared.

Body 12: Regular Crooksville body.

Body 13: Same as No. 10, except mixed at plant.

Body 14: Flux content (syenite C) equal to present feldspar content plus an additional 1.5% at the expense of flint content.

III. Preparation of Bodies

One hundred pounds dry weight of bodies 9 and 10 were prepared at the Engineering Experiment Station, Ohio State University, in the following manner.

* Received July 18, 1936.

[1] (*a*) C. J. Koenig, "Use of Syenite in Semivitreous Ware: I, Physical Properties of Bisques and a Glaze Containing Syenite," *Jour. Amer. Ceram. Soc.*, **19** [10] 295–98 (1936).

(*b*) For preliminary reports see *Ceram. Ind.*, **25** [6] 338 (December, 1935); *Ceram. Age*, **27** [1] 262 (1936).

[2] For Table I, see p. 295 of reference in footnote 1.

In weighing, allowance was made for the water content of the ball clays and other materials when it exceeded 1 or 2%. The materials were blunged with warm water for about 2½ hours in a propeller-type blunger at a specific gravity of about 1.3. They were passed through a 120-mesh screen and a magnetic separator and then filter-pressed at 60 to 70 pounds pressure. The filter cakes were placed in a mixing machine to distribute the moisture evenly. Unfortunately, some air was inadvertently entrapped in this operation, all of which could not be removed by wedging at the pottery. For this reason, body No. 10 was repeated, being mixed at the plant in the accepted test manner, and this procedure was also adopted for the other bodies.

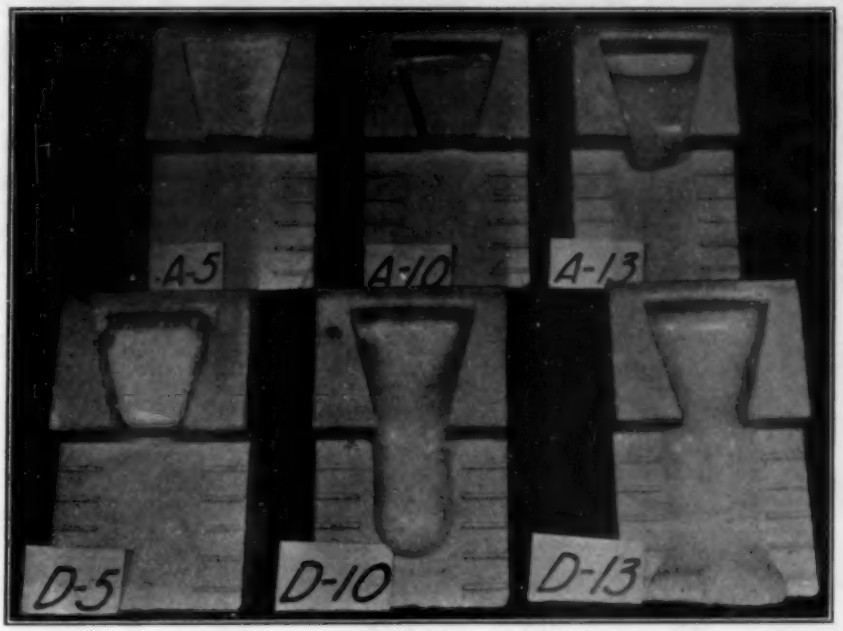

FIG. 1.—(A) potash feldspar (North Carolina); (D) nepheline syenite (Ontario, Canada); the numbers represent cones.

IV. Firing

In all cases except body 14, the test ware was bisque-fired at cone 9 and glost-fired at cone 5 in the tunnel kiln of the Crooksville China Company. Owing to the uniformity of temperature maintained in its kiln, no attempt was made to obtain values from different cross-sectional positions. Body 14 was bisque- and glost-fired at cone 4.

V. Results

Values for modulus of rupture and elasticity are averages of ten or more determinations. Values for warpage and shrinkage were calculated from tests on two to three dozen 5-inch plates. Absorption and coefficient of expansion determinations were made in duplicate, and all remaining tests were conducted on at least three specimens.

VI. Discussion of Results

The potency of syenite C as a vitrification agent is clearly shown by the fact that although it was introduced in amounts equal only to 65% of the present feldspar content, it produced an absorption of 8.5% when fired to cone 9. By replacing the feldspar content with syenite C plus an additional 1.5% at the expense of the flint content, firing can be conducted at about four cones lower than present practice. Thus body 14, when fired to cone 4, had an absorption of about 9%. This same body, when fired to cone 9, had an absorption of 1.2%. Ninety-five per cent of normal flux content as syenite F produced slightly more vitrification than the normal feldspar content.

Body 9, in which the flint content had been increased to replace a portion of the flux content, showed less firing shrinkage than the regular body, but in the other cases the firing shrinkage was only slightly less than the regular body.

Modulus of rupture and elasticity values each fell a little above and a little below that of the regular body. The body fired at cone 4 was a little above that of the regular body in this respect.

The warpage of the bodies 9, 10, and 13, containing syenite, fired at cone 9, compared favorably with the regular body. Body No. 14, which was bisque- and glost-fired at cone 4, showed a higher warpage than the regular body. Most of this, however, occurred in the glost fire. Apparently, in order to bisque fire at cone 4, the glost fire should be reduced to cones 1 or 2.

Ware from bodies 9 and 10 were remarkably free from warpage and stacked beautifully. This freedom from warpage can perhaps in part be attributed to a difference in consistencies of these bodies, as previously discussed, when the plates were jiggered. The results of body 13 in this respect were as anticipated from laboratory findings.

All the plates passed the autoclave test of 150 pounds for 1 hour. Body 14 and the regular body showed excellent resistance to crazing and dunting in the quenching test, and the remaining bodies, while not so good in this respect, were still satisfactory, surpassing some other commercial semivitreous ware tested.

The highest impact resistance was given by syenite body 9, the next by body 10, while the others, including the regular body, were nearly equal in value.

The highest resistance to chipping was shown by the cone 4 syenite body, and body 13 was intermediate between it and the remaining bodies, all of which were nearly the same in this property.

On the other hand, it was found that bodies having a high coefficient of expansion at 250°C were more likely to fail by dunting than by crazing, and in those cases where failure of syenite

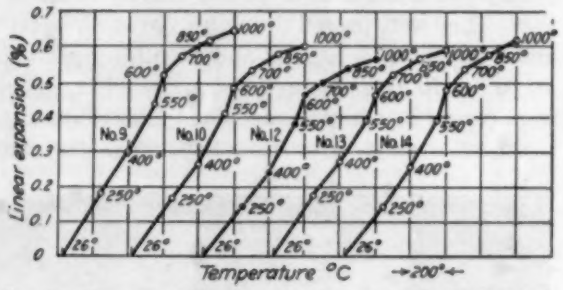

FIG. 2.—Percentage linear expansion curves for body specimens indicated.

bodies occurred in the heat-shock test it was always due to dunting.

It is not surprising that nepheline syenites, owing to their soda content, promote higher coefficients of expansion in semivitreous bodies than do potash feldspars, inasmuch as soda feldspars are reported to act similarly in this respect.

TABLE II

TESTS ON FIVE-INCH PLATES

Body No.	9 Syenite C	10 Syenite F	11 Potash feldspar	12 Potash feldspar	13 Syenite F	14 Syenite C
Ratio to normal flux content (1)	0.65	0.95	1	1	0.95	1.13
Warpage (in.)	0.040	0.042	0.068	0.073	0.054	0.087
Autoclave test (150 lb. for 1 hr.)	O.K.	O.K.	O.K.	O.K.	O.K.	O.K.
Heat shock 200°C to water (26°C) no. of quenchings	4 plates O.K. after 10 quenchings; 1 failed at 8th quenching	Av. failure of 6 plates 8 quenchings	3 plates O.K. after 10 quenchings	3 plates O.K. after 10 quenchings	Av. failure 6 plates 6 quenchings	4 plates O.K. after 10 quenchings
Impact value (in.-lb./in.)	8.67	7.1	6.3	6.1	6.0	6.3
Chipping value (ft.-lb.)	0.04	0.04	0.04	0.04	0.05	0.06

Syenite body No. 9 had the highest coefficient of thermal expansion and the feldspar body the lowest. Loomis[3] found that a fairly close relationship existed between the coefficient of expansion at 550°C and the resistance of the glazed ware to crazing and that bodies high in this respect at 550°C were not likly to fail by crazing. All of these syenite bodies have a higher coefficient of expansion at 550°C than the feldspar body, and in keeping with this generalization none of these has failed by crazing in the heat-shock test.

Bodies 9, 10, 11, 12, and 13 were nearly alike in color, whereas body 14 was darker.

VII. Microstructure of Bodies[4]

(1) Method of Investigation

The specimens examined were thin sections prepared from pieces which had been broken from 5-inch plates. The methods employed consisted of the usual petrographic examination using the polarizing microscope.

The photomicrographs were taken at a magni-

[3] G. A. Loomis, "Study of Domestic Ball Clays in Ivory Earthenware Bodies," *O.S.U. Eng. Expt. Sta. Bull.*, No. 69, 55 pp. (May, 1932); p. 31.

[4] An excellent review of literature on the microstructure of whiteware bodies is given by C. L. Norton, Jr., "The Influence of Time on the Maturing Temperature of Whiteware Bodies: II," *Jour. Amer. Ceram. Soc.*, **14** [3] 192–206 (1931).

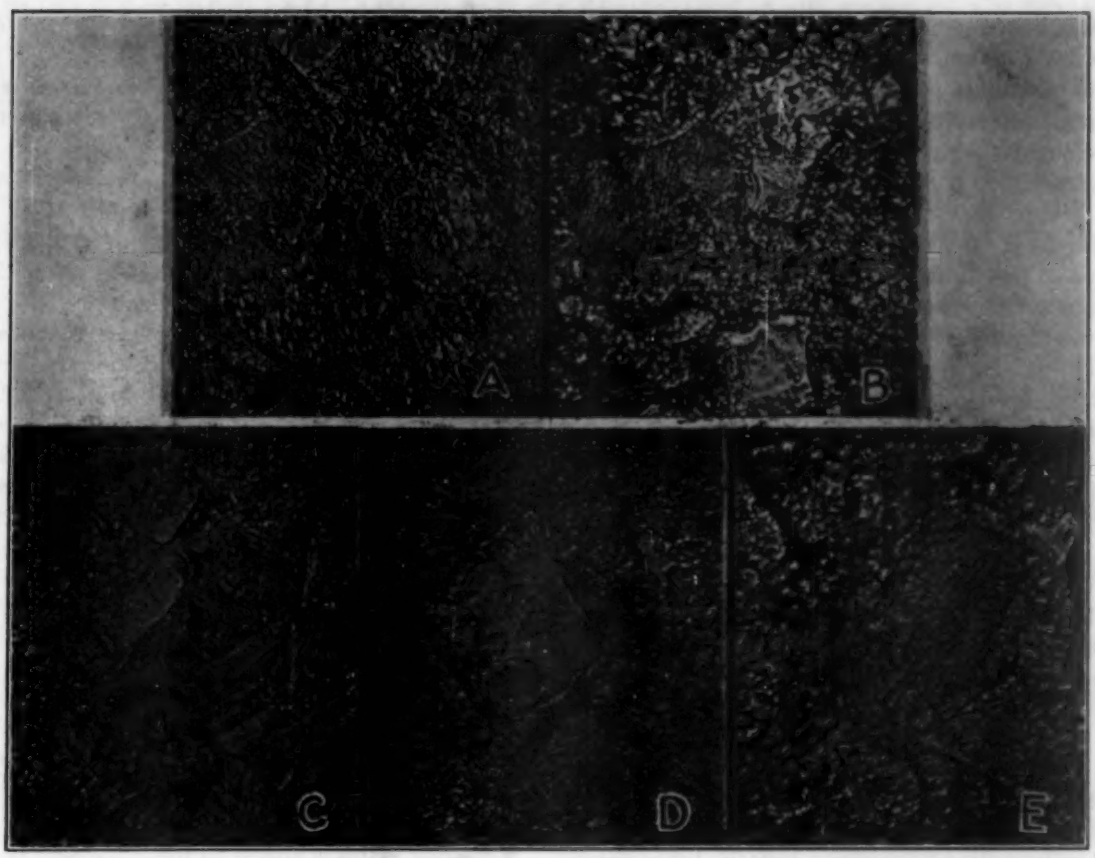

FIG. 3.—(*A*) body No. 9 (cone 9, absorption 8.5%); (*B*) body No. 12 (cone 9, absorption 7.6%); (*C*) body No. 13 (cone 9, absorption 7.2%); (*D*) body No. 14 (cone 4, absorption 8.9%); and (*E*) body No. 14 (cone 9, absorption 1.2%).

fication of 900 diameters, which was produced by an oil-immersion objective (aperture 1.30), an ocular of 8 magnifications, and the necessary camera-bellows extension. The illuminating source was a Mazda projection tube with a Wratten B (green) filter.

(2) Discussion

The source of mullite ($3Al_2O_3 \cdot 2SiO_2$) crystals in a body of this type is the clay, since it is the only constituent which contains a sufficient amount of alumina to develop these crystals. The clay gradually breaks down under the influence of the melted feldspar ($K_2O \cdot Al_2O_3 \cdot 6SiO_2$) to form amorphous mullite and silica glass, and as the reaction continues the mullite particles increase in size.

The feldspar contains some alumina but has only one molecule of alumina for six of silica. In bodies containing nepheline syenite, however, the presence of nepheline ($Na_2O \cdot Al_2O_3 \cdot 2SiO_2$) as well as the feldspars must be considered. Since nepheline is considerably richer in alumina than feldspar, it would seem that mullite development would occur more readily in grains of nepheline than in grains of feldspars. The amount of nepheline in the several syenites studied varied appreciably. Thus the nepheline content of the syenite used in bodies 10 and 13 is secondary in amount to the feldspars, whereas in bodies 9 and 14, nepheline is the predominating mineral. The first development of mullite in these bodies takes place in the feldspar and nepheline grains. These grains have not lost their outlines and are present as pseudomorphs.

The size of the mullite needles increases with increasing glassy development. Thus body 14 (absorption 1.2%) fired to cone 9 showed the greatest development of mullite and quartz solution, whereas the same body fired to cone 4 showed no visible quartz solution and scarcely any development of mullite.

The quartz grains in Fig. 3 (*A*) show no perceptible solution. There is an incipient development of mullite present as a needlelike structure in pseudomorphs of feldspar or nepheline grains. The angular grain is quartz and the large grain is a pseudomorph of feldspar largely transferred to mullite.

Figure 3 (*B*), body No. 12, is practically the same as body No. 9. Angular quartz grains and a large pseudomorph of feldspar largely transferred to mullite are shown.

The quartz grains in Fig. 3 (*C*) show no apparent attack judged from their angularity. Numerous quartz grains and also a pseudomorph of feldspar or nepheline possessing fairly definite outline are shown.

The quartz grains in Fig. 3 (*D*) show no solution, and comparatively little development of mullite is discernible.

In Fig. 3 (*E*) the quartz grains, especially the smaller ones, show indications of quartz solution. The mullite needles are well defined in the center.

VIII. Summary

Semivitreous bodies indicating promising results were prepared (1) by introducing the syenites in reduced amounts and (2) by counteracting the greater fluxing action of the syenites as compared to feldspar by reducing the firing temperature. When the bisque fire is reduced, it is necessary to reduce also the glost fire; otherwise warpage occurs in this fire. The use of syenites should favor fuel economy.

When the syenites were introduced in reduced amounts and bisque- and glost-fired, as in present practice, less warpage occurred.

The syenite bodies showed a higher coefficient of expansion than the feldspar body.

For the same degree of absorption, values for modulus of rupture and elasticity fell in about the same range.

Five-inch glazed plates made from these bodies passed satisfactorily the chipping, impact, heat shock, and autoclave tests.

The first development of mullite in these bodies takes place in the nepheline and feldspar grains. These grains have not lost this original outline and are present as pseudomorphs. The size of the mullite needles increases with increasing glassy development.

Additional References

(1) A. A. Klein "Constitution and Microstructure of Porcelain," *Bur. Stand. Tech. Paper*, No. 80, 38 pp. (1916).
(2) Herbert Insley, "Microstructure of Earthenware," *Jour. Amer. Ceram. Soc.*, **10** [5] 317–26 (1927).
(3) A. B. Peck, "Effect of Time and Temperature on the Microstructure of Porcelain," *ibid.*, **2** [3] 175–94 (1919).

Acknowledgments

The writer wishes to express his indebtedness to G. A. Bole for his helpful advice, to the Crooksville China Company for their whole-hearted coöperation, and to the several companies who supplied the raw materials.

Engineering Experiment Station
Ohio State University
Columbus, Ohio

THE EFFECT OF SMALL ADDITIONS OF BENTONITE AND BALL CLAY TO A WHITEWARE MIXTURE*

By J. W. Whittemore

Abstract

Varying amounts of ball clay and bentonite were added to a whiteware mixture. The effect of the additions on the plasticity and other physical properties was studied.

I. Introduction

There are several ways by which plasticity and bond may be improved, such as the additions of plastic clays, flocculation, and grinding in water. Cox[1] found that by mixing 10, 20, 30, 40, and 50% of bentonite with calcined Florida clay and raw North Carolina kaolin, plasticity could be obtained that was of the same quality as that found in high-grade ball clays.

To obtain some comparison of the effect of additions of bentonite and ball clay in whiteware mixtures, various amounts of these materials were added to a porcelain mixture[2] consisting of 50% kaolin, 30% quartz, and 20% feldspar, and the physical properties of the various mixtures were determined.

Note: For the porcelain mixture, the materials used were a Florida kaolin, potter's flint, and feldspar. The ball clay used was a mixture of 50% Champion and 50% Challenger ball clay. The Wyoming bentonite was furnished by the American Colloid Company.

II. Procedure

Three-pound batches of the porcelain mixture with 0, 2.5, 5.0, 7.5, and 10% additions of bentonite were prepared, as well as 3-pound batches with 0, 2.5, 5.0 7.5, 10, and 20% additions of ball clay; each was thoroughly blunged and dried at 100°C. Enough tempering water was used to produce the best working consistencies when the batches were pugged.

The plasticity was determined in a plasticimeter,[3] and the batches were extruded through a $1^1/_8$- by $1^1/_8$-inch die by a hydraulic piston extrusion machine and cut into samples $4^1/_2$ and $1^1/_8$ inches in length. The long specimens were used for the determination of strength and the short specimens for the determination of weight and volume.

The volumes were obtained in a mercury displacement volumeter[4] accurate to 0.1 cubic centimeter and the weights were determined on a balance accurate to 0.01 gram.

The water of plasticity, pore water, dry and fired shrinkage, dry and fired strengths, and absorption were determined according to standard methods.[5]

III. Laboratory Results

(1) Plastic Properties

The plasticity (Table I) produced by the addition of 2.5% bentonite greatly exceeded the plasticity produced by any addition of ball clay up to and including 10%. The specimens containing

Table I*

Plasticity

Additions (%)	Bentonite	Ball clay
0.00	0.0063	0.0063
2.50	.0134	.0074
5.00	.0160	.0087
7.50	.0183	.0091
10.00	.0212	.0097

* Values in this table indicate plasticity figures.

2.5% bentonite were more firm and had sharper corners and edges than all the specimens containing additions of ball clay.

(2) Properties When Dried

Since the amount of tempering water needed to produce the best working consistency varied, the water of plasticity fluctuates slightly, but with additions of bentonite, the water of plasticity remains fairly constant, and with ball clay additions the tendency is to decrease (Table II).

With additions of bentonite, the water of plasticity remained fairly constant and the pore water showed a slight tendency to decrease, thus increasing the amount of shrinkage water with a resulting increase in shrinkage. With the additions of ball clay, up to and including 10%, the water of plasticity and the pore water were re-

* Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, April 1, 1936 (White Wares Division).

[1] P. E. Cox, "Study of Plasticity by Practical Potter's Methods," *Jour. Amer. Ceram. Soc.*, **7** [3] 151–53 (1924).

[2] F. H. Riddle and W. W. McDanel, "Some Types of Porcelain," *ibid.*, **1** [9] 606–27 (1918); p. 607.

[3] J. W. Whittemore, "Mechanical Method for the Measurement of the Plasticity of Clays and Mixtures of Clays," *ibid.*, **18** [11] 352–59 (1935).

[4] J. F. McMahon, "Improved Mercury Volumeter," *ibid.*, **13** [5] 363–67 (1930).

[5] *Jour. Amer. Ceram. Soc.*, **11** [6] 448 (1928).

TABLE II

Additions (%)	Water of plasticity (%)		Pore water (%)		Volume shrinkage (%)		Modulus of rupture (lb./sq.in.)	
	Bentonite	Ball clay	Bentonite	Ball clay	Bentonite	Ball clay	Bentonite	Ball clay
0.00	23.72	23.72	18.41	18.41	9.26	9.26	66	66
2.50	22.86	22.48	17.03	17.20	10.28	9.40	399	88
5.00	23.30	21.46	17.04	16.67	11.31	8.50	558	135
7.50	23.51	21.89	17.09	17.21	11.86	8.15	746	89
10.00	24.28	21.00	17.11	17.04	12.51	8.04	852	113
20.00		22.39		17.91		10.30		173

duced. The water of plasticity was reduced to a greater extent than the pore water, so that there was less shrinkage water and less shrinkage in drying. The addition of 20% ball clay increased the shrinkage materially (see Table II).

Bentonite and ball clay reduced the pore water about equally. The particles of bentonite and ball clay probably surround the nonplastic particles and partially fill the interstices of these nonplastics, thus reducing the amount of pore space. Apparently, additions of more than 2.5% did not fill the pores to any greater extent.

With increased additions of bentonite and ball clay, there was greater plasticity of the mass and more mobility of the particles. This enabled a better adjustment and closer fit of these particles and brought more of their surface areas into contact with each other, allowing molecular attraction to hold them in their relative positions. This also increased the dry modulus of rupture of the specimens, more so with bentonite than with ball clay.

Table II shows the improvement in the dry modulus of rupture. The addition of bentonite caused an increase in strength of 500, 745, 1030, and 1191%, respectively. The ball-clay additions caused an increase in strength of 33, 105, 34, 71, and 162%, respectively.

(3) Fired Properties

After firing to cone 1, there is an increase in the volume shrinkage with increased additions of bentonite and ball clay (Table III). More shrinkage was produced by the bentonite than by the ball clay. The closer fit of the particles in the plastic and dried states and the greater area of contact enabled reactions to take place more easily with the formation of a glassy matrix, which would necessarily cause an increase in shrinkage, greater strength, reduced absorption, and greater vitrification. It has been found[6] that the addition of bentonite lowers the P.C.E., while ball clay affects the P.C.E. but slightly. This point is shown clearly by the reduction in the absorption and increase in modulus of rupture by the additions of bentonite as compared with the negligible effect of the ball clay. The alkalis and other impurities in the bentonite also aid in the formation of the glassy

TABLE III

PROPERTIES AFTER FIRING TO CONE 1

Additions (%)	Volume shrinkage (%)		Absorption (%)		Modulus of rupture (lb./sq.in.)	
	Bentonite	Ball clay	Bentonite	Ball clay	Bentonite	Ball clay
0.00	1.50	1.50	20.03	20.03	382	382
2.50	2.26	1.69	19.31	20.10	876	394
5.00	3.17	1.91	17.71	20.07	1285	422
7.50	3.77	2.48	17.45	20.25	2021	486
10.00	3.91	2.57	16.35	20.08	2207	499

matrix and partially explain the increase in shrinkage and strength and the lowering of the P.C.E. The addition of bentonite had no effect on the fired color of the specimen.

IV. Conclusions

It is realized that ball clay is essential in whiteware for the development of a filled body, but if the manufacturer should use bentonite judiciously with the ball clay, he could expect to secure (1) increased plasticity and ease of forming, (2) increased dried and fired modulus of rupture, (3) increased dried and fired shrinkage, (4) no discoloration of ware after firing, and (5) increased vitrification.

The advantages gained by the addition of bentonite in increasing the plasticity and the strength both when dry and when fired outweigh the disadvantages of the increase in shrinkage during drying and firing. With certain types of whiteware bodies, these objections would not exist at all.

Too large additions of bentonite have caused various difficulties in the manufacture of whiteware. Very small additions, however, greatly improve the physical properties and probably would not cause the difficulties frequently encountered in plant operations. This paper, however, is limited to the laboratory investigation.

VIRGINIA POLYTECHNIC INSTITUTE
BLACKSBURG, VIRGINIA

[6] H. T. Coss, "Bentonite in Ceramic Bodies," *Ceram. Age*, **17** [3] 147–49 (1931); *Ceram. Abs.*, **10** [7] 521 (1931).

PARTICLE PACKING AND PARTICLE SHAPE*

By H. E. White† and S. F. Walton‡

Abstract

Spherical particles of equal size theoretically may be packed in five different ways, *e.g.* (1) cubical with a theoretical void space of 47.64%, (2) single-staggered or cubical-tetrahedral with a theoretical void space of 39.55%, (3) double-staggered with a theoretical void space of 30.20%, (4) pyramidal, and (5) tetrahedral; the void spaces in the latter two are identical, 25.95%.

Secondary, ternary, quaternary, and quinary spheres each set smaller than its predecessor, may be fitted into the voids in this last type of packing and the voids reduced theoretically to 14.9%.

The use of very fine filler in the remaining voids will then reduce the voids theoretically to 3.9%.

The use of particles of elliptical shape does not appear to reduce the porosity, but cylindrical-shaped particles, if properly arranged, would reduce the porosity below that possible with spheres.

The practical application of these theoretical methods of packing was studied, and the possibility of crushing ceramic materials to spherical shapes is discussed with particular emphasis on the higher-priced materials such as fused alumina, mullite (fused, synthetic, and natural), chromite, magnesite, forsterite, silicon carbide, and also silica, owing to the particular rounded character of natural sand grains.

Study of experimental work shows the possibility of approaching the theoretical densest packing arrangement by the use of spherical-shaped grains. Allowance must be made in some instances for the porosity of the grains themselves.

Surface areas can be calculated and the bonding mediums proportioned accordingly. Some commercial refractories investigated, which have relatively low porosity, seem to have taken advantage of a careful study of the laws of particle packing, both in the manner of packing of the grog grains and in the shape of the grains themselves.

I. Introduction

Owing to the emphasis on low porosity, a vast amount of data, established from practical experience, have been published on the packing of ceramic grog particles, using the materials at hand and deducing empirical formulas to fit these data.

Little information is available on the fundamental knowledge of particle packing and particle shape and the evolution therefrom of ceramic bodies of high density, *i.e.*, low porosity.

Beginning with cubical materials, if all particles could be crushed in cubical shape and packed cubically, the porosity of the resultant body naturally would be zero, provided, however, that air absorption were negligible.

If the solids have condensed air films around them so that they do not come actually in contact, the percentage of voids will go up with decreasing size of the solids. As a matter of fact, voids in carbon black may run up to 95%.

In the normal crushing of cubes, it would be expected that the corners would be knocked off and a polyhedron, approaching a sphere, would result.

In a cubical unit volume packed with spheres, the percentage of voids is the same, whether there is one sphere or a number of spheres of equal size, as long as their diameters are exact multiples of the unit and are piled so that each sphere is directly on top of the other in a cubical fashion.

This is not true of any other type of unit or style of packing. Spheres packed in cylinders, as in the usual tests for grog volumes, give different results.

In cubical-unit packing of spheres, the voids are 47.64% of the whole.

A single sphere of diameter, d, in a cylinder of diameter and height, d, gives $33^1/_3$% voids, while eight equal spheres of maximum size to pack cubically in the same cylinder give 42.5% voids. As the spheres become smaller in relation to the cylinder diameter, cubical unit volume is approached.

The difference between the theoretical values

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Part of the Symposium on "The Production of Dense Aggregates." For the Introduction to this Symposium by N. W. Taylor and papers by R. S. Dean and F. O. Anderegg see *Bull. Amer. Ceram. Soc.*, **16** [1] 7–13 (1937).

† Lava Crucible Company of Pittsburgh, Zelienople, Pa.

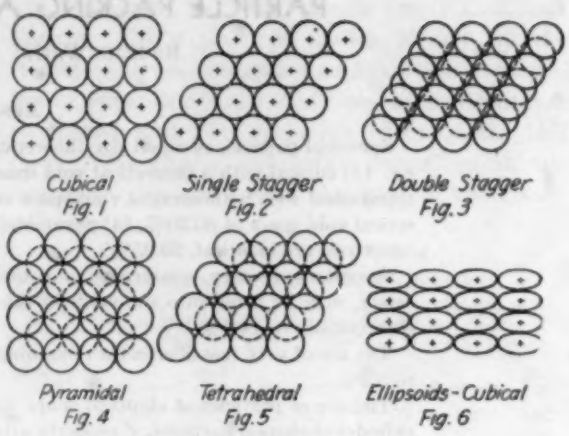
‡ Exolon Company, Blasdell, N. Y.

and the actual values as found under certain experimental conditions is shown by a statement "that large enough masses of equal-sized marbles can not be poured or tamped into a large vessel so as to give less than 44% voids." Undoubtedly in time these would have jarred down so as to occupy a lesser volume as later experimental work shows.

Water-rounded sand grains have 2 to 5% less voids than corresponding sharp grains because the former pack better.

The effect of moisture on sand is also unexpected. Moist sand occupies more space per unit weight, *i.e.*, it weighs less per cubic foot, based on the actual weight of the sand less the water, than dry sand packed in the same manner. The explanation of this anomaly is that a film of water coats each grain of sand and separates it from the adjacent ones.

Litehiser[1] shows the increase and subsequent decrease in the bulk of sand by addition of water (see Table I). The percentage voids were calculated by the writers from the data given using the specific gravity of quartz (2.65). These data have been reproduced by Sutherland and Clifford.[2]



FIGS. 1–6.

(1) Theory

The pore space in an aggregate then depends on the ratio between the size of the particles, their shape, and their packing arrangement.

(2) Types of Packing

Spheres of equal diameter can be packed in a regular manner in five simple ways, *e.g.* (1) cubical, (2) single-staggered or cubical-tetrahedral, (3) double-staggered, (4) pyramidal, and (5) tetrahedral as shown in Figs. 1 to 5. The full circles represent spheres in one plane, while the dotted lines indicate the spheres in the next layer.

In cubical packing (Fig. 1), each sphere touches four other spheres in the same layer and every layer is the same, the highest point of the spheres in the lower layer contacting the lowest point in the upper layer.

In single-stagger packing (Fig. 2), each sphere touches six of its neighbors in the same layer, and again the highest points in the lower layer contact the lowest points in the upper layer.

Double-stagger packing (Fig. 3) is the same as single except that the spheres in the upper layer rest in the depression between two adjacent spheres in the lower layer.

Pyramidal packing (Fig. 4) arranges the spheres

TABLE I

	Dry rodded	Dry loose	Loose	Loose	Loose	Loose	Loose	Loose	Loose
Water by weight (%)	0	0	1	2½	5	7½	10	15	17½
Wt./cu. ft. (inc. water (lb.))	115.0	106.0	98.3	90.5	85.5	91.5	94.6	104.5	136.0
Wt. dry sand in 1 cu. ft.	115.0	106.0	97.3	88.4	81.4	85.1	86.0	90.9	115.0
Voids (%)	30.6	36.0	41.3	46.7	50.8	48.6	48.2	45.2	30.6

Westman and Hugill[3] actually attained as low as 36.9% voids for lead shot in a cylindrical tube and 37.7 to 42.5% for rounded, washed sand of approximately equal size, the higher figure being with the finer sizes. Undoubtedly tetrahedral or pyramidal packing resulted as well as some difference in particle size.

The photographic studies accompanying this report show the variation in particle shape possible with the same materials either through natural selection, different crushing methods, or both.

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[1] R. R. Litehiser, "Effect of Moisture in Sands in Proportioning Concrete Mixtures," *Concrete* (1925).

[2] Hale Sutherland and W. W. Clifford, Reinforced Concrete Design, pp. 26–27. John Wiley & Sons, New York, 1926.

[3] A. E. R. Westman and H. R. Hugill, "Packing of Particles," *Jour. Amer. Ceram. Soc.*, **13** [10] 767–79 (1930).

so that each sphere in one layer contacts four other spheres in the same layer as in cubical packing, but each sphere of the upper layer rests in the depression between four adjacent spheres in the lower layer.

Tetrahedral packing (Fig. 5) is arranged as in single stagger, but the upper layer has each sphere resting in the depression between three adjacent spheres in the layer below.

II. Mathematical Calculations for Various Types of Particle Packing

With a cube of $2r$ dimension, the volume is $8r^3$.

A sphere which touches all six sides has a diameter of $2r$ and a volume of $\frac{4\pi r^3}{3}$. The percentage of void space is then

$$\frac{8r^3 - {}^4/_3\pi r^3}{8r^3} = \left(1 - \frac{\pi}{6}\right) 100 = 47.64\%.$$

Spheres of diameter $\frac{2r}{x}$ have a volume of $\frac{4\pi r^3}{3x^3}$. If x is the number of spheres that exactly fill each side of the cube, the total volume in the spheres becomes $\left(\frac{4\pi r^3}{3x^3} \cdot x^3\right) = \frac{4\pi r^3}{3}$ and the void space is the same.

Most manufactured refractory shapes are not perfect cubes because they have unequal sides, and the following reasoning may be applied. If the radius of the spheres is denoted by r and the number of spheres along each of the axes, x, y, and z, is nx, ny, and nz, respectively, then the volume of the empty space or void for an infinite number of spheres may be calculated as follows:

Cubical packing (Fig. 1)

A = volume of solid-figure bounding spheres
$= 2rNx \cdot 2rNy \cdot 2rNz$
$= 8r^3Nx \cdot Ny \cdot Nz.$

Volume of spheres $= \frac{4}{3}\pi r^3 Nx \cdot Ny \cdot Nz$

$$= \left(\frac{8r^3 - \frac{4}{3}\pi r^3}{8r^3}\right) 100.$$

Volume of void space expressed in percentage of total = 47.64%.

Single-stagger or cubical-tetrahedral packing (Fig. 2)

Volume of solid-figure bounding spheres
$= 2rNx \cdot r\sqrt{3}Ny \cdot 2rNz$
$= 4r^3\sqrt{3}Nx \cdot Ny \cdot Nz.$

Volume of spheres $= \frac{4}{3}\pi r^3 Nx \cdot Ny \cdot Nz.$

Volume of void space expressed in percentage of total

$$= \left(\frac{4\sqrt{3} - \frac{4}{3}\pi}{4\sqrt{3}}\right) 100 = 39.55\%.$$

Double-stagger packing (Fig. 3)

Volume of solid-figure bounding spheres
$= 2rNx \cdot r\sqrt{3}Ny \cdot r\sqrt{3}Nz$
$= 6r^3Nx \cdot Ny \cdot Nz.$

Volume of void space expressed in percentage of total

$$= \left(\frac{6r^3 - \frac{4}{3}\pi r^3}{6r^3}\right) 100$$

$$= \left(1 - \frac{4}{18}\pi\right) 100 = 30.2\%.$$

Pyramidal packing (Fig. 4)

Volume of solid-figure bounding spheres
$= 2rNx \cdot 2rNy \cdot r\sqrt{2}Nz$
$= 4r^3\sqrt{2}Nx \cdot Ny \cdot Nz.$

Volume of void space expressed in percentage of total

$$= \left(\frac{4r^3\sqrt{2} - \frac{4}{3}\pi r^3}{4r^3\sqrt{2}}\right)$$

$$= \left(\frac{1 - \pi\sqrt{2}}{6}\right) 100 = 25.95\%.$$

Tetrahedral packing (Fig. 5)

Volume of solid-figure bounding spheres
$= 2rNx \cdot r\sqrt{3}Ny \cdot 2r\sqrt{\frac{2}{3}}Nz$
$= 4r^3\sqrt{2}Nx \cdot Ny \cdot Nz.$

Volume of void space expressed in percentage of total

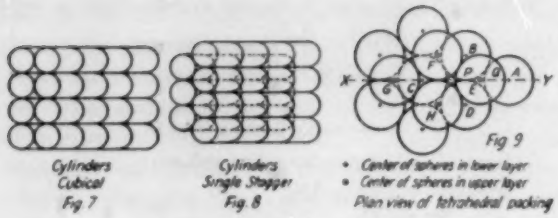
$$= \left(\frac{4r^3\sqrt{2} - \frac{4}{3}\pi r^3}{4r^3\sqrt{2}}\right) 100 = 25.95\%.$$

TABLE II

Fig. No.	Type of packing of spheres	Unit prism (Vol.)	Voids (%)
1	Cubical	$8r^3$	47.64
2	Single stagger (cubical tetrahedral)	$4r^3\sqrt{3}$	39.55
3	Double stagger	$6r^3$	30.20
4	Pyramidal	$4r^3\sqrt{2}$	25.95
5	Tetrahedral	$4r^3\sqrt{2}$	25.95

III. Calculation for "Filler" Spheres

Thus the densest packing of spheres of equal size gives 26% of void space and this is independent of the diameter of the spheres. To reduce the volume of this empty space still further, it is necessary to add other spheres of such size that they will fit into the irregular-shaped pockets between the primary spheres without displacing them. Further reduction is effected by adding still smaller spheres which fit into the spaces between the primary and secondary spheres; then,



FIGS. 7–9

by use of ternary, quaternary, and quinary spheres, the voids can be successively reduced until the sphere used becomes so small that the boundary effect is negligible and the voidage remaining is 26% of the void space existing prior to the introduction of the filler.

The investigation of this close packing by use of progressively smaller spheres was made, starting with spheres packed as in the tetrahedral system (Fig. 5). These spheres, as shown, are called primary spheres. All of the voids in this arrangement are connected, but pockets of two different sizes are contained between the spheres. The largest sphere that can be introduced into each of the larger pockets is called a secondary sphere. A tertiary sphere is the largest that can be contained in one of the smaller pockets. The largest sphere that can then be introduced was calculated and is called the quaternary sphere; a quinary sphere was then calculated.

IV. Calculation of Sphere Sizes and Voids (Tetrahedral System)

Figure 9 shows in plan a number of primary spheres arranged in two layers in the tetrahedral system. Figures 10 to 13 show vertical sections on the line, XY. The dotted circles indicate spheres which are not cut by the section.

In Fig. 10, the height between the layers is ET. P is the point of contact between the two spheres, the centers of which are at B and D in Fig. 9.

(1) Primary Sphere

If r = radius of each primary sphere, $AP = r\sqrt{3}$. $AT = 2/3r\sqrt{3}$. $AE = 2r$. $ET^2 = AE^2 - AT^2 = \frac{8r^2}{3}$.

$ET = 2r\sqrt{(2/3)}$ = height between layers.

(2) Secondary Sphere

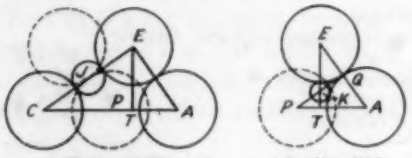
$CT = CP + PT = r\sqrt{3} + (r/3)\sqrt{3} = \frac{4}{3}r\sqrt{3}$. $ET = 2r\sqrt{(2/3)}$. $CE^2 = CT^2 + ET^2 = 8r^2$. $CE = 2r\sqrt{2}$.

The largest sphere that can be introduced into the pocket bounded by the six spheres of centers B, C, D, E, F, and H will have its center on the line, CE, because the void is symmetrical. As the center lies on CE, its contacts with the spheres, C and E, will also lie on that line. Hence, if r_2 = radius of secondary sphere, $2r + 2r_2 = CE$ and $r_2 = r(\sqrt{2} - 1) = 0.414r$.

(3) Tertiary Sphere

Inasmuch as the pocket between spheres A, B, D, and E is symmetrical about any of six planes, K, the center of the tertiary sphere, must lie in the plane of EA and the contact, P, between spheres, B and D. Similarly the center must lie on the plane of BD and the contact, Q, between spheres, A and E. This plane is represented by the line, PQ, in Fig. 11.

The center must also lie vertically below E on the line ET, which is the trace of two other planes of symmetry.



Triangles AET, EKQ are similar.
Therefore, $EK/EQ = AE/ET$. $EK = EQ \cdot AE/ET = r \cdot \frac{2r}{2r\sqrt{(2/3)}} = r\sqrt{(3/2)}$; but $EK = r$ + radius of tertiary sphere, r_3. Therefore the radius of the tertiary sphere, $r_3 = 0.225r$.

(4) Quaternary Sphere

Surrounding each secondary sphere there are eight small pockets yet unfilled. Into each of these, a quaternary sphere can be introduced. The axis of one of these pockets is the vertical line, JU. The center, L, of the quaternary sphere will lie on this axis and will make contact with spheres C and J (Fig. 12).

FIGS. 10–14.

$JU = ET/2 = r\sqrt{2/3}$.
Let r_4 = radius of quaternary sphere.
$JL = 0.414r + r_4$. $CL = r + r_4$. $CU = (2r/3)\sqrt{3}$.

$LU = r\sqrt{(2/3)} - 0.414r - r_4 = 0.402r - r_4$.
$CU^2 = CL^2 - LU^2 = 0.838r^2 + 2.804rr_4$.
Therefore the radius of quaternary sphere,
$r_4 = 0.495r/2.804 = 0.177r$.
Note: $0.414r$ (radius of secondary sphere) + $(0.177r)2 = 0.768r$. $JU = 0.816r$.

This means that the edge of the quaternary sphere is $0.048r$ above line CP.

(5) Quinary Sphere

Surrounding each tertiary sphere are four quinary spheres. One of these will have its center, M, on the axis, ET, of the pocket (Fig. 13).

Let r_5 = radius of quinary sphere.
$AM = r_5 + r$.
$AT = (2r/3)\sqrt{3}$. $KT = ET - EK = r/\sqrt{6}$.
$MT = KT - KM = 0.408r - r_5 - 0.225r = 0.183r - r_5$.
Since $MT^2 + AT^2 = AM^2$. $r_5 = 0.155r$.

Though this sphere can be introduced into the void space surrounding a tertiary sphere, it will be seen that a part lies beyond the line, AP. $ET = 2r\sqrt{2/3} = 1.632r$. $r + 2r_3 + 2r_5 = 1.760r$. This means that the pocket, corresponding to the one containing sphere, K, on the opposite side of AP can not be filled with a tertiary and a quinary sphere. It can be arranged that there are larger secondary pockets adjoining each pocket containing a tertiary sphere. This means that no two tertiary pockets adjoin. The advantage of this arrangement can be seen from Figs. 12 and 13.

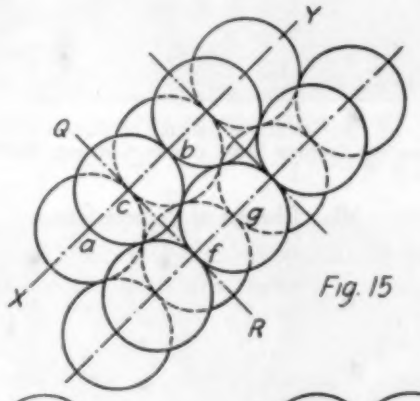
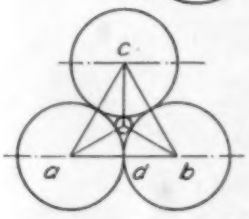
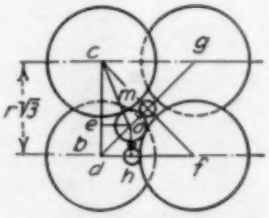


Fig. 15



Section through XY
Fig. 16



Section through QR
Fig. 17

FIGS. 15–17.

Because the quaternary sphere, L, lies clear of the axis, CP, there is room for a quinary sphere to transgress the axis to a small extent ($0.048r$), while the quinary sphere overhangs $0.072r$. In Fig. 13, J' is a secondary sphere in a secondary pocket and K is a tertiary sphere in a tertiary pocket. Connecting the two pockets is a constricted passage which is partly filled by a quaternary sphere, L', and a quinary sphere, M.

A size has been calculated for the quinary sphere based on its relation to the tertiary sphere, K, and the surrounding primary spheres, A, B, and D.

The size must now be calculated to conform to a second set of conditions, *viz.*, that the sphere shall lie between the tertiary sphere, K, and the quaternary sphere, L'.

$ET = 2r\sqrt{(2/3)}$. $J'T = r\sqrt{(2/3)}$.
$EJ' = r\sqrt{2} \cdot \sqrt{3} = 2.449r$.

The maximum diameter of the quinary sphere, $M = EJ'$ − (radius of sphere E) − (diameter of sphere K) − (diameter of sphere L') − (radius of sphere J') $= 2.449r - r - 0.450r - 0.354r - 0.414r = 0.235r$. Therefore the radius of the quinary sphere $= 0.116r$. As this is less than $0.155r$, the radius calculated by considering the first set of conditions, it follows that the size of the quinary sphere is determined by its relationship to the adjacent quaternary and tertiary spheres. Then the quinary sphere lies only $0.050r$ below AP, whereas the quaternary sphere is $0.048r$ below AP and is still a tight fit.

Table III gives the number of spheres of each size and the voids remaining after their addition.

The figures show that, if spheres of certain sizes are carefully packed together by the tetrahedral system, the voids may be reduced to 14.9% and if filler of extreme fineness be used in addition the voids are further reduced to 3.9%. This packing is much more dense than anything yet achieved in practice and the grading is quite unlike that usually adopted.

V. Calculation of Sphere Size and Voids (Double-Stagger System)

In the double-stagger packing, the arrangement is quite irregular. The secondary spheres are much smaller than in tetrahedral packing and the number also varies.

Inasmuch as true packing is undoubtedly a cross between double-stagger and tetrahedral, the calculations for the former have also been made.

TABLE III

RELATIVE SIZE OF SPHERES (TETRAHEDRAL SYSTEM)

	E	*J*	*K*	*L*	*M*	Filler
Radius of sphere	r	$r_2 = 0.414r$	$r_3 = 0.225r$	$r_4 = 0.177r$	$r_5 = 0.116r$	Very small
Relative no. of spheres	1	1	2	8	8	
Vol. of sphere	$4.189r^3$	$0.298r^3$	$0.0476r^3$	$0.0225r^3$	$0.0066r^3$	
Vol. of spheres added	$4.189r^3$	$0.298r^3$	$0.0952r^3$	$0.180r^3$	$0.0526r^3$	$0.622r^3$
Total solid vol. of spheres in mixture	$4.189r^3$	$4.487r^3$	$4.582r^3$	$4.762r^3$	$4.815r^3$	$5.437r^3$
Voids in mixture (%)	25.95	20.7	19.0	15.8	14.9	3.9
Weight of spheres in final mixture (%)	77.08	5.47	1.75	3.31	0.97	11.42
Total surface area of spheres in mixture	$12.566r^2$	$14.732r^2$	$16.004r^2$	$19.080r^2$	$20.456r^2$	

E = primary; *J* = secondary; *K* = tertiary; *L* = quaternary; *M* = quinary.

The secondary sphere is in a pocket bounded by spheres *a*, *b*, *c*, and *f* (Fig. 15), and has its center on a line perpendicular to the median point of great circles of spheres *a*, *b*, *c*, and *a*, *b*, *f*, whose intersection, *o*, is the center of the sphere.

mo = radius of secondary sphere = $r_2 = co - r$ (Fig. 17).

$co = \sqrt{eo^2 + ce^2}$.

$r_2 = (\sqrt{eo^2 + ce^2}) - r$.

$eo = {}^1/_3 r\sqrt{3} = 0.577r$.

$ce = cd - ed = r\sqrt{3} - 0.577r$.

$r_2 = (\sqrt{(0.577r)^2 + (1.155r)^2}) - r = 0.2845r$.

The tertiary sphere lies between each set of three spheres.

$r_3 = ce - r = 0.155r$; there are four of these (Fig. 16).

The quaternary sphere, $r_4 = {}^1/_2 dg - do - r_2$

$$= \frac{r\sqrt{6}}{2} - \frac{r\sqrt{6}}{3} - 0.285r$$

$= 0.123r$; there are two of these (Fig. 17).

The quinary sphere lies between r_2 and r_3 on the line *ho* (Fig. 17).

$ho = {}^1/_3 r\sqrt{3} = 0.577r$.

$2r_5 = ho - r_3 - r_3$.

$r_2 + r_3 = 0.440r$.

$2r_5 = 0.137r$.

$r_5 = 0.068r$; there are four of these.

There is another sphere between r_4 and r which has a radius $0.052r$ and still another slightly larger in the pocket next to this one.

will not take place in practical experiments with shot, sand, or grog particles, this exact grading is not ideal. The sole value of the theoretical grading is that it gives an indication of the proportions of various sizes which are likely to give low-void mixtures.

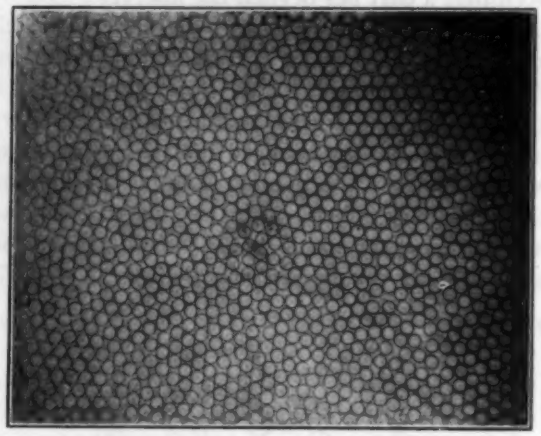


FIG. 18.—Natural packing of glass tubing. (Courtesy Corning Glass Works, Corning, N. Y.)

VI. Change of Particle Shape

The possibility of changing the shape of the particle was studied with particular reference to

TABLE IV

TABLE SHOWING RELATIVE SIZE OF SPHERE (DOUBLE-STAGGER SYSTEM)

	Primary	Secondary	Tertiary	Quaternary	Quinary
Radius of sphere	r	$0.285r$	$0.155r$	$0.123r$	$0.068r$
Relative number	1	2	4	2	4
Vol. of sphere	$4.189r^3$	$0.0971r^3$	$0.0156r^3$	$0.0078r^3$	$0.0013r^3$
Total solid volume	$4.189r^3$	$4.383r^3$	$4.445r^3$	$4.461r^3$	$4.466r^3$
Voids (%)	30.2	26.8	25.9	25.6	25.5

Table IV gives the size and quantity of each sphere and the voids remaining after its addition.

The absolute minimum voidage in packed spheres by any system of packing is obtained only when each one goes into its proper place. As this

the packing of ellipsoids and cylinders with the following results:

Cubical packing of ellipsoids (Fig. 6)

$$V = \frac{\pi}{6} \cdot a \cdot b^3.$$

FIG. 19.—Grog of high alumina type showing agglomerated particles which in themselves tend toward high porosity (5 ×).

a = large diameter; b = small diameter.

Volume of solid-figure bounding ellipsoids

$= aNx \cdot bNy \cdot bNz$
$= ab^2(Nx \cdot Ny \cdot Nz)$.

Volume of ellipsoids $= \frac{\pi}{6}ab^2(Nx \cdot Ny \cdot Nz)$.

Volume of void space expressed in percentage of total

$$= \frac{ab^2 - \frac{\pi}{6}ab^2}{8ab^2} = \left(1 - \frac{\pi}{6}\right) = 47.64\%.$$

Cubical packing of cylinders (Fig. 7)

Volume of solid-figure bounding cylinder

$= 2rNx \cdot 2rNy \cdot LNz$.

Volume of cylinders $= \pi r^2 LNx \cdot Ny \cdot Nz$.
Volume of void spaces expressed in percentage of total

$$= \frac{4r^2L - \pi r^2L}{4r^2L} = \frac{4 - \pi}{4} = 1 - \frac{\pi}{4} = 21.46\%.$$

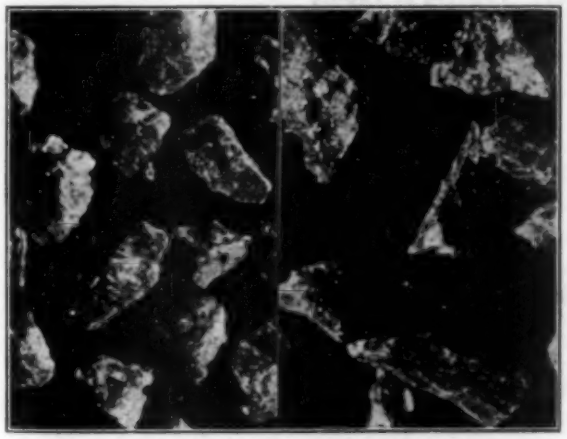


FIG. 20 (*left*).—Aluminum oxide, rounded.
FIG. 21 (*right*).—Aluminum oxide, sharp. (5 ×).

Single-stagger packing of cylinders (Fig. 8)

Volume of solid-figure bounding cylinders

$= 2rNx \cdot r\sqrt{3}Ny \cdot LNz$
$= 2r^2L\sqrt{3}$.

Volume of void space expressed in percentage of total

$$= \frac{2r^2L\sqrt{3} - r^2L}{2r^2L\sqrt{3}} = \frac{2\sqrt{3} - \pi}{2\sqrt{3}} = 1 - \frac{\pi}{2\sqrt{3}} =$$
$$1 - 0.906 = 9.40\%.$$

Secondary cylinders for single-stagger packing of cylinders (Fig. 14)

$AD = r\sqrt{3}$; $AE = 2/3r\sqrt{3}$.

r_{11} (radius of secondary cylinder) $= 2/3r\sqrt{3} - r = 0.155r$.
Volume of secondary cylinder, $V = \pi(0.155r)^2L$
$= 0.075r^2L$.
Resulting voids of primary and secondary cylinders

$$= \frac{2\sqrt{3} - (\pi + 0.075)}{2\sqrt{3}} \cdot 100 = 7.21\%.$$

The possibility of the use of cylindrical grog (see Figs. 7 and 8) is not fantastic as evidenced by some kyanite particles as well as by those of flake graphite which are, in reality, cylinders of very short height in relation to their diameter.

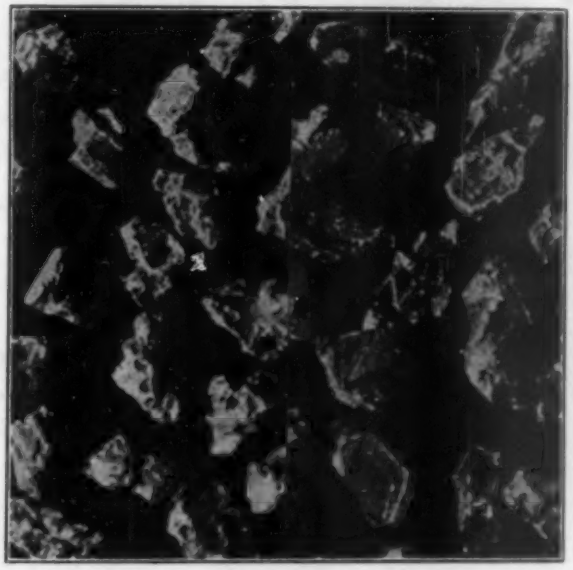


FIG. 22 (*left*).—Silicon carbide, rounded.
FIG. 23 (*right*).—Silicon carbide, sharp (5 ×).

In recent attempts in the manufacture of dense refractory shapes, methods of manufacture have been modified to take advantage of this denser packing of grog particles as a means of reducing porosity.

A manufacturer in the paper and cloth abrasive industry is said to arrange the abrasive grains on the glued surface by means of an electrostatic charge, so that the largest area rests in the glue

and the point is exposed to do the cutting. Thus both maximum adhesion and sharpness are attained.

Developments such as this might assist in resolving grog particles into their proper relation, one to another in refractory bodies.

VII. Utilization of Aggregate

The possibility of packing particles for maximum density using the aggregate at hand was investigated by Vieser[4] in a study of concrete aggregates, who made the following deductions:

Sieving operations do not yield particles of equal size, but the average size of the largest particle measures about three-fourths of the clear opening of the largest sieve and the smallest size, expressed in terms of the clear opening of the largest sieve, is about one-twelfth of the latter.

The computation of voids will be based on the assumption that the voids of a certain size are filled by one-fourth the quantity of fine particles (of $^1/_{16}$ diameter); the remaining parts are then treated as a mixture in a similar manner, etc. A density of 0.62 will be assumed for a mixture of four sizes, as well as for particles of one size. The density of an arbitrarily selected but not rationally graded mixture will be assumed as 0.62; the density of a correctly graded mixture will be figured in accordance with the number of sizes: $0.62(1 + {}^1/_4) = 0.775$ or $0.62(1 + {}^1/_4 + {}^1/_{16}) = 0.814$. If all sizes are represented down to the infinitesimally small, the latter value is raised to 0.827 $(0.62 \cdot {}^4/_3)$. For the sake of simplicity of procedure, the density of an arbitrary mixture and that of a uniform size was selected as 0.62; this seems justifiable as it is our purpose to obtain comparative and not absolute values. A more accurate analytical treatment of these intricate relations is hardly possible and we must content ourselves with one or the other assumption. From the deductions which follow we will become convinced that this assumption is adequate.

Assuming three groups, the particles of (*e*) of the second group fit the coarse particles (*a*) of the first group and are of a magnitude of the "filler particles" in Table III (p. 160). The second sets ((*f*) and (*b*)) likewise are of a size to fit in the ratio 75 to 25. There is sufficient remaining from the second group to require the addition of a still finer third group, resulting in the calculated void space of 19.5%.

TABLE V

	Size (in.)	(%)	Volume (cu. m.)				
(*a*)	2.52 –1.23	29.805	29.805				
(*b*)	1.23 –0.63	21.226		21.226			
(*c*)	0.63 – .32	15.116			15.116		
(*d*)	.32 – .16	10.765				10.765	
(*e*)	.16 – .08	7.666	7.451				0.215
(*f*)	.08 – .04	5.460		5.306			.154
(*g*)	.04 – .02	3.888			3.779		.109
(*h*)	.02 – .01	2.769				2.691	.078
(*i*)	.01 – .005	1.972	1.863				.109
(*j*)	.005– .0025	1.404		1.426			.022

Parts: 0.51031·0.814 = 0.415
0.25881·0.775 = 0.205
0.00643·0.620 = 0.004

0.7755 cu. m. vol. 0.624 cu. m. solid

The compacting effect of tamping and mixing on a mixture mass of this kind amounts to 1.0 − 0.775 = 0.225 or 22.5% (as against 15 and 20%, respectively, for aggregates (*a*) and (*b*); the solid mass per cu. m. is $\left(\frac{0.624}{0.7754} = 0.805\right)$ or 0.805 cu. m.; the volume of pores is 19.5%.

[4] W. Vieser, "Proportioning Concrete," *Zement* (Sept. 2–Oct. 14, 1926).

(1) Packing of Tubing

In the natural packing of glass tubing, it is possible to observe two systems of packing, one tetrahedral and the other cubical, although the latter is quite infrequently and poorly arranged (see Fig. 18).

VIII. Particle Shape

Some years ago grog particles were a necessary evil added to aid manufacture. With present-day refractories, containing as high as 95% grog, the grog forms the more essential part of the refractory and the properties of the refractory are usually attributed to the grog particles themselves. The problem at present is to find suitable bonding mediums.

Even in blocks cast from molten material, the

TABLE VI

SHOWING VOID SPACE REMAINING AFTER PACKING OF PARTICLES

(a) Single materials (each determination on single size)

Material	Diameter or mesh size	Specific gravity	Packed vol. (g./cc.)	Voids (%)	Reference
Lead shot	0.19	11.25		36.9	Westman
	.15	11.25		36.9	"
	.11	11.25		37.0	"
	.07	11.25		36.9	"
	.048			36.6	White
Lead shot, loose packed	.05	11.32	6.35	43.9	Walton
Lead shot, jolted	.05	11.32	6.90	39.0	"
Sand, 4–6 mesh	.176	2.69		37.7	Westman
Sand, 20–28 "	.028	2.76		38.2	"
Sand, 48–65 "	.0097	2.76		38.6	"
Sand, 150–200 "	.0035	2.75		42.5	"
SiC grain (run-of-mill), −14 +16	.046 / .039	3.136	1.75	48.1 / 47.3 / 46.3	White
Silicon carbide, rounded	−0.066 + 0.055	3.22	1.78	44.72	Walton
Silicon carbide, angular	−0.066 + 0.055	3.20	1.50	53.12	"
SiC fines (run-of-mill)	+100 − 1.1%	3.23	1.75	45.9	White
	+150 − 7.2			46.4	"
	+200 −33.7			43.2	"
	−200 −57.4			48.9	"
Kyanite −14 +16				40.5	"
Flint clay −14 +16			1.37		
Aluminum oxide, rounded	−0.066 +0.055	4.00	2.37	40.75	Walton
Aluminum oxide, angular	− .066 + .055	4.00	2.19	45.25	"
Mullite (rounded)	− .066 + .055	3.29	1.86	43.47	"

(b) Two materials (coarse and fine sizes)

	Diameter or mesh size	Proportion of mix			
Lead shot	0.048	100 (by packed vol.)	11.25	15.1	White
+ SiC fines	+100 − 1.1% +150 − 7.2 +200 −33.7 −200 −57.4	27 " " "	3.23		
Silicon carbide and clay mix (rammed)			3.00	2.68	10.7	Walton

(c) Single materials, various sizes

SiC grain	−14 +16	100 (by packed vol.)		29.8 / 32.1	White
+ SiC fines (as in (*b*))		34.3 " "			
Silicon carbide mix	−0.066 + .0555	75% (by weight)	3.20	2.105	34.2	Walton
	−0.0083 and finer	25% " "			
Silicon carbide run-of-mill mix			3.20	2.12	33.7	"
Mullite mix	−0.066 + .0555	75% (by weight)	3.29	2.19	33.7	"
	−0.0070 and finer	25% " "			
Aluminum oxide (theoretical mix)	−0.0661 +0.0555	77% " "	3.98	2.70	32.2	"
	−0.0232 + .0165	5.5 " "			
	−0.0165 + .0098	1.8 " "			
	−0.0098 + .0070	3.5 " "			
	−0.0059 + .0041	1.0 " "			
	−0.0029 and finer	11.2 " "			

structure is by no means uniform in the strictest sense for it consists of crystals of two or more kinds embedded in a glassy matrix. Blow-holes or pipes also occur in the center, and the crystallization varies widely between the outer edge and the center.

The sources of refractory grog are (1) calcination of lump clay direct from the mine (usually flint or some flint clays); (2) calcination of raw clay, after grinding, wetting, and molding into blocks of convenient size; (3) grinding of used refractories; and (4) nonplastic materials, such as sillimanite, silica, crystalline alumina, silicon carbide, etc.

It has been generally agreed that sharp, angular particles are required. Rees[8] is of the opinion that in the transverse test, which is a good measure of the binding strength, grog of angular shape shows to advantage.

[8] W. J. Rees, "Notes on Analysis of Refractories," *Jour. Soc. Glass Tech.*, **11** [42] 172–76 (1927); *Ceram. Abs.*, **6** [10] 445 (1927).

Comparison, however, has yet to be made using the above proposed grading. The angular particles undoubtedly supply the filler for some of the voids, but properly graded and packed spherical

FIG. 24.—Mullite, rounded (5 ×).

particles should give minimum porosity, closest interfacial contact, and therefore the highest strength.

IX. Experimental Work

The packing of particles of different materials was studied as well as the work of other investigators, and the following data were accumulated.

The method used by White was essentially that described by Westman,[3] except that the packing tube was usually kept under vacuum of 70 to 70.5 centimeters mercury which materially assisted the packing. Walton packed his samples by jolting by hand in a 100-cubic centimeter graduate.

With porous or agglomerated materials, such as silicon carbide, the voids were determined by the amount of water necessary to fill the voids.

It has been determined that in the coarse-grained silicon carbide (−14 + 16) there are 48.1% voids. Using 175 grams (100 cu. cm. packed

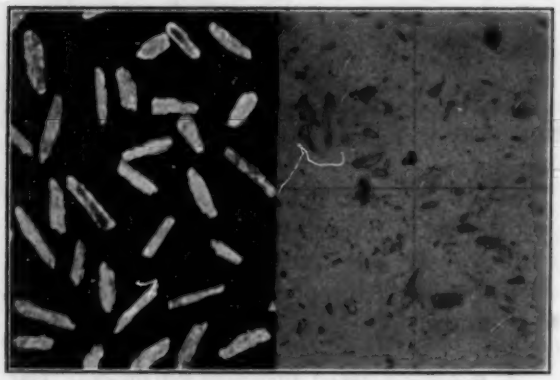
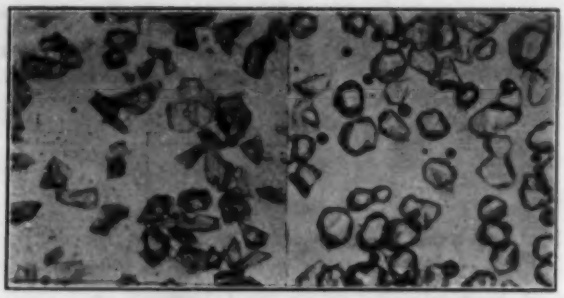


FIG. 25 (*left*).—Kyanite, coarse (natural size).
FIG. 26 (*right*).—Kyanite, fine (−200-mesh)(20 ×).



FIGS. 27 and 28.—Electrically fused MgO (5 ×). Angular (left); rounded (right).

volume) of the −14 + 16 and 60 grams (34.3 cu. cm. packed volume) of the fines −150- + 250-mesh material, the measured voids were 32.1% − 29.8%.

By calculation, 48.1 − 34.3 = 13.8% voids are left between coarse and fine particles and not filled owing to the deficiency of fine particles.

Then 34.3 × 0.464 (percentage voids in fines) = 15.87% voids in fines themselves or a total of 29.67% voids, which is close to the measured figure.

It is difficult to obtain correct packing without segregation, using the theoretical maximum quantity of fines, so the above experiment was made to illustrate the relation between theory and practice.

Using the theoretical proportions of flint-clay particles, however, and assuming them to be spheres, it was not possible to attain the theoretical packing density as given in Table VII.

This gave a void space of 32.9 − 33.5% and packed to a density of 1.465 grams per cubic centimeter against a theoretical void space of 3.9% and packed 1.69 grams per cubic centimeter.

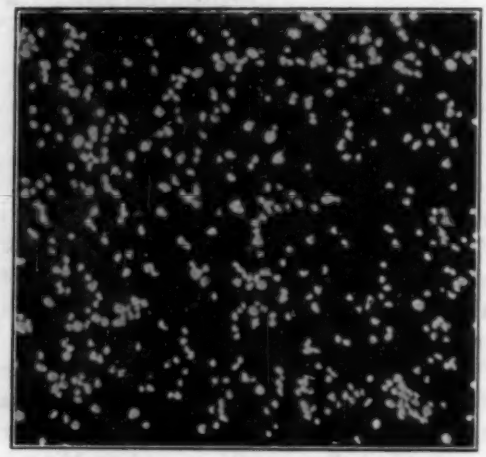


FIG. 29.—Bonded MgO, particles recrushed (natural size).

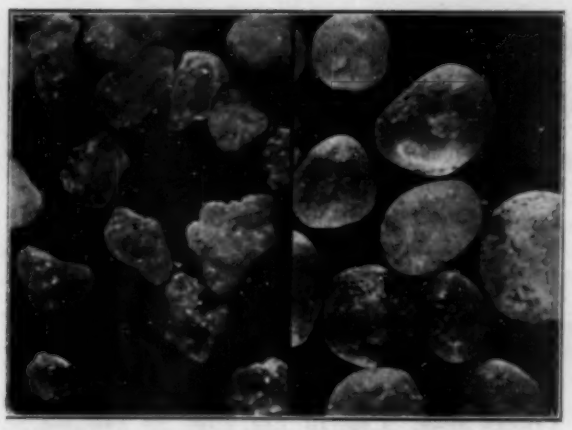


FIG. 30 (*left*).—Silica sand (Virginia marine) (10 ×).
FIG. 31 (*right*).—Silica sand (Wisconsin residual).

TABLE VII

	Screen opening	Av. particle size	Voids (%
− 14 + 16-mesh	0.046 .039	0.042	77.0
− 30 + 40- "	.0232 .0164	.0198	5.5
− 40 + 60- "	.0164 .0097	.0130	1.75
− 60 + 80- "	.0097 .0069	.0083	3.5
−100 + 150- "	.0058 .0041	.00495	1.0
− 200- "	.0029		11.25

Some experiments were carried out, using two- and three-component sizes and are shown in Table VIII.

It seems evident that surface area must be taken into consideration, as the coarser aggregate gives less dense packing.

It is also evident that the hand-tamped and bumped method, similar to that of Westman and others, is limited to particles of one size or those mixtures whose porosity is above 25%.

Proper particle packing, therefore, depends both on theory and practice. The shape and physical condition of the grog must be considered and its packing characteristics determined.

Naturally the regularity of packing can not be attained with irregular-shaped particles.

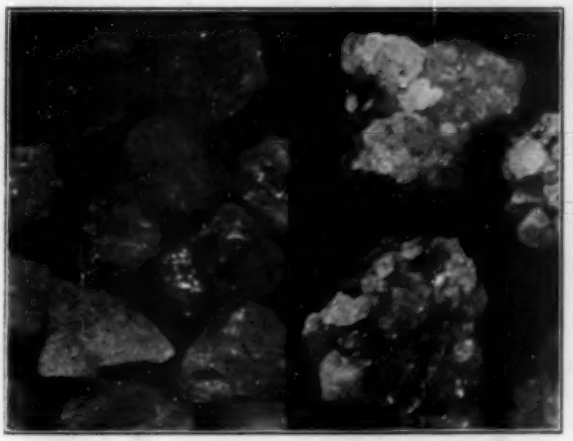


FIG. 32 (*left*).—Silica sand (Virginia marine) (10 ×).
FIG. 33 (*right*).—Pennsylvania sand, Oriskany, 12-mesh, crushed and unwashed.

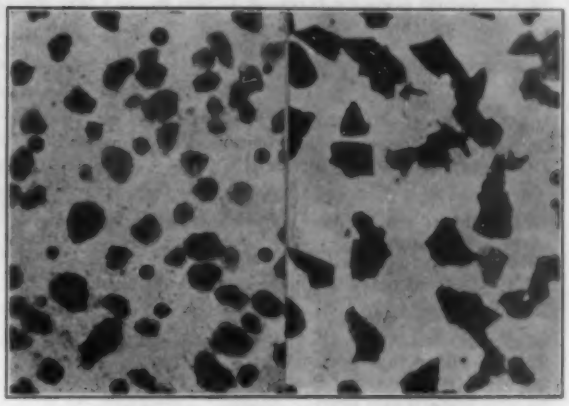


FIG. 34 (*left*).—Ganister particles (5 ×).
FIG. 35 (*right*).—Flake graphite (5 ×).

X. Crushing of Grog

Clays and used refractories are usually first crushed in jaw crushers and subsequently in dry pans or rolls. This type of crushing is not conducive to rounded grains except where solid-bottom dry pans are used.

Used refractories tend to give agglomerated particles on recrushing.

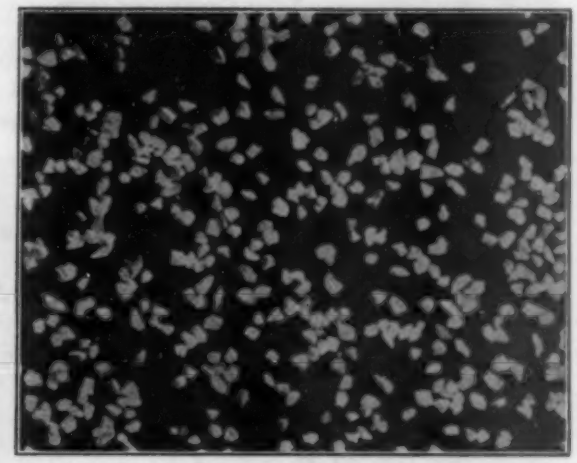


FIG. 36.—Flint clay (natural size).

TABLE VIII

Flint clay

137 g. (100 cu. cm. packed volume) −14- + 16-mesh
55 g. −200-mesh
16% theoretical porosity
25.6% actual porosity (hand-tamped and bumped)
18.5% actual porosity (pressed 10,000 lb./in.² and fired to cone 18)

137 g. −4- + 6-mesh
55 g. −48- + 60-mesh
22 g. −200-mesh
6.5% theoretical porosity
24.4% actual porosity (hand-tamped and bumped)
19.8% actual porosity (pressed)

Silicon carbide

175 g. (100 cu. cm. packed volume) −14- + 16-mesh
60 g. −200-mesh
29.7% theoretical porosity
25.45% actual porosity (hand-tamped and bumped)

175 g. −14- + 16-mesh
84 g. −200-mesh
22.31% theoretical porosity
25.9% actual porosity (hand-tamped and bumped)
23.4% pressed and fired

Special refractories lend themselves easier to special crushing methods, because, on the whole, they are much harder and stronger.

The variation in particle size between screen sizes is another point to be considered.

Packing methods are worthless unless particle-size ratios are strictly maintained; 100% mesh of one size is practically impossible, but 75 to 80% is easily attained.

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TABLE IX

COMPARISON OF QUALITIES OF REFRACTORY BRICK

Base material	Specific gravity base	Av. density of brick	Usual present porosity (%)	Possible porosity (%)	Weight 9-in. brick (lb.)	
					At present	Possible
Fused alumina	3.98	2.73	18	4	10	14.0
Mullite (natural converted clay bond)	3.18	2.31	18	5	8.5	11.0
Mullite (electric furnace) clay bond	3.24	2.38	18	4.5	8.75	11.3
Mullite	3.25	2.87	2	0	10.52	12.25
Molten cast	3.35					
Forsterite	3.22			5		11.25
Graphite (clay bond)	2.31	1.64	25	10	6.0	7.62
Periclase	3.64	3.13	18	4	11.5	12.80
Silica	2.30–2.40	2.05	25	5	7.50	8.20
Silicon carbide	3.21	2.39	18	6	8.75	11.10
Magnesite	3.44–3.60	3.00	20	6	11.00	12.10
Chrome	3.86	3.27	18	6	12.00	13.30
Chrome-magnesite	3.799	3.14	17	5	11.50	13.25
Flint clay	2.64	2.01	20	7	7.37	9.02
Chrome (organic bond unfired)	3.48	2.95	11.94	4	10.80	12.25
Magnesite (organic bond unfired)	3.69	3.20	13.26	4	11.70	13.0
Clay glass tank blocks (1)	2.52	2.03	18.65	6	7.45	8.65
Clay glass tank blocks (2)	2.52	2.10	16.95	6	7.72	8.65
Clay glass tank blocks (3)	2.52	2.20	12.35	5	8.05	8.75
Clay glass tank blocks (4)	2.52	2.25	10.83	5	8.25	8.75

SIZE DISTRIBUTION OF CERAMIC POWDERS AS DETERMINED BY A PARTICLE-SIZE AIR ANALYZER*

By Paul S. Roller

Abstract

The use of air as a fluid for analytical separation of microscopic-size particles has been given a new impetus by the development of a system involving a dynamic relationship between the powder sample and the air jet. This relationship is such that the powder charge is caused to circulate automatically and at the same time to translate in a direction opposite to that of the incoming air. Particle-size analysis embodying this principle is described with the samples consisting of ceramic materials. Advantages of the air-separation method of analysis are discussed.

I. Air as a Separating Medium

The present-day ready availability of an air supply directs attention to the use of air as a separating medium in microscopic particle-size analysis. The technique of using air is concerned exclusively with securing discrete-size fractions by floating them quantitatively in an air current regulated as to its velocity.

In general, when compared with water as a separating medium, air has the following advantages: The rate of fall of a particle in air is, on the average, about 100 times greater than in water so that the rate of separation with air is intrinsically much greater than with water, tedious removal of liquid from the separated material is not required, little attention need be paid to temperature since the temperature coefficient of viscosity is only about 0.6% per°C for air as against 2.2% for water, and alteration of the crystals by reaction with the water or by adsorption of deflocculant is not encountered. The last-named advantage is of particular importance when fractions are desired for study and experimentation.

When compared with what have been termed indirect methods of analysis[1] that depend on measurement of some property related to size, such as light-scattering,[2] adsorption, rate of solution, and so forth, separation by means of air offers the advantage of depending only on a simple law of particle fall (Stokes' law). Even this, however, is not accepted without qualification since a check on Stokes' law and on the operation may always be had by examining the fractions obtained under the microscope.

Sedimentation analysis, as by the collection method (pipette, balance) or density method (hydrometer, manometer), also depends only on a simple law of particle fall. Aside from other matters, however, it is presumed here that deflocculation is complete in one treatment and that no reflocculation takes place during settling while, furthermore there is no direct check on the process. In physical separation of the powder by means of air, however, the powder is continuously subject to the deflocculating action of the jet until all of a given size has been floated off and weighed. Indirect methods, while useful and perhaps unavoidable for the smallest microscopic and submicroscopic particles, because of theoretical complexity and incomplete assurance of a true result are much less justified for particles in the microscopic range.

II. Problems of Air as a Separating Medium

(1) Previous Apparatus

Particles in the microscopic range below 20μ are attracted by surface forces which must be overcome if separation is to be effected. In liquid methods, dependence for this is obtained by mechanical shaking and stirring in the presence of a deflocculant. With air, dependence is secured on the strength of a jet. The air jet must be strong enough to effect deflocculation but not strong enough to break down the crystal itself.

The use of such a jet introduces the difficulties of residual high-speed air currents in the settling chamber and especially of dislocation and immobilization of the powder sample. A suitable de-

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[1] P. S. Roller, "Separation and Size Distribution of Microscopic Particles: An Air Analyzer for Fine Powders," *Bur. Mines Tech. Paper*, No. 490, 46 pp. (1931).

[2] Compare in this respect to R. N. Traxler and L. A. H. Baum, "Measurement of Particle-Size Distribution by Optical Methods," *Proc. A.S.T.M.*, **35** [Part II] 457–67 (1935); *Ceram. Abs.*, **15** [4] 127 (1936).

sign must recognize and overcome these difficulties.

In one of the earlier designs,[3] the jet, at about 0.8-inch Hg pressure, is pointed downward into the powder sample, obviously with the idea that the powder charge after dislocation upward will fall back into contact with the jet. The main fallacy in this procedure lies in the fact that the rising deflocculated particles come into contact with the falling powder sample and are thereby reflocculated. Circumstances, furthermore, are favorable for the entrance of high-speed air currents into the settling chamber. Aside from these more important disadvantages, the Gary and Lindner system suffers from lack of provision for quantitative regulation of the air and from the use of irregular glass settling chambers.

The last-named secondary defects were overcome by Pearson and Sligh,[4] but the essential part dealing with the relation of jet to powder sample remained the same.

(2) Present Apparatus

After some experimentation the writer decided[1] that what was needed was a dynamic system of jet and powder sample in which the sample would move uniformly into and against the force of the jet instead of the static system that had previously been used. The advantages of the new system were immediately apparent in the greatly improved results obtained.

The original apparatus[1] and that improved mechanically[5] have been described in detail, and only the more important and new features will be referred to here.

The present apparatus has settling chambers, $1^1/_4$ to 9 inches in diameter, spring tapper for shaking down particles suspended in the lower cone, gooseneck and paper-extraction thimbles for collecting and weighing the fractions, and capillary-glass flowmeter.

The glass U-tube which contains about 20 cubic centimeters of powder sample is caused to oscillate against the action of a spring and abutment by impacts of the rubber-tipped hammer at the right. The inlet tube entering the glass U-tube at the left supplies the air jet. Owing to the constrained oscillations of the U-tube the powder sample moves automatically in the opposite direction to the force of the jet, while at the same time due to the slope of the sample an inner circulation of the particles is obtained. Deflocculated particles are blown clear of the sample by the jet, while discharged flocculates and reflocculates fall back into the U-tube to reunite with the main powder sample and thus to be reëxposed to the action of the jet. It should be noticed that, in the absence of such a dynamic relation between jet and powder sample, the latter would be blown over to one side of the tube and immobilized as far as effective separation at small sizes is concerned. On the other hand, a haphazard shaking of the powder sample instead of an orderly motion is almost equally bad, as it gives rise to drastic reflocculation. Baffling of the jet through nearly 180° of the U-bend before the air enters the settling chamber insures the absence in the chamber of residual high-speed currents.

The lower cone is designed so that the angle is greater than the angle of repose even of the finest material. The spring tapper, by speeding the downward fall of particles sliding along the cone, speeds up the rate and regularity of separation of the finer fractions without, however, affecting the percentage result. For example, the following result was obtained for the 0 to 5μ fraction in the analysis of a cement: without the tapper, 19.0% by weight, time to end-point 130 minutes; with the tapper, 19.2%, time to end-point 75 minutes.

Disagreeable sound overtones may be eliminated by providing the tapper with a leather tip. A further expedient consists in housing the apparatus in a suitable cabinet. This may have a separate advantage as discussed below under dust adherence (p. 173).

Traxler and Baum[6] use a shaft with double cam so that two separations may be effected simultaneously.

In this laboratory instead of the force fit originally used, it is now customary in addition to hold the fitted paper thimble securely to the

[3] M. Gary, "Report on Problem 30," International Assn. Testing Mat., Brussels Congress (1906).

[4] J. C. Pearson and W. H. Sligh, "An Air Analyzer for Determining the Fineness of Cement," *Bur. Stand. Tech. Paper*, No. 48, 74 pp. (Sept. 8, 1915).

[5] P. S. Roller, "Measurement of Particle Size with an Accurate Air Analyzer: The Fineness and Particle-Size Distribution of Portland Cement," *Proc. A.S.T.M.*, **32** [Part II] 607–25 (1932); *Ceram. Abs.*, **12** [3] 117 (1933).

[6] R. N. Traxler and L. A. H. Baum, "Determination of Particle-Size Distribution in Mineral Powders by Air-Elutriation," *Rock Prod.*, **37** [6] 44–47 (1934); *Ceram. Abs.*, **13** [10] 268 (1934).

rubber stopper by means of a Gooch rubber, fastened to the stopper and rolled over the edge of the thimble.

(3) Procedure

The procedure is simple and involves essentially weighing, at regular intervals, the material which collects in the paper thimbles. At each interval, both gooseneck and thimble are removed after tapping the gooseneck and are replaced by another gooseneck with thimble fastened thereto.

For all separations the nozzle, which screws into the inlet, is chosen of such size that the pressure is 1.0 to 1.5 inches of mercury. Experience shows that this pressure is not great enough to disrupt the grains but is strong enough to effect complete deflocculation. The air is filtered, and, for the finest fraction, is dehumidified by bubbling it through 50% sulfuric acid.

The air velocity is regulated strictly in accordance with Stokes' law of fall, so as to float a particle of maximum desired size.[1] To this end, it is convenient to tabulate the air velocity against the density of the material. This has been done in Table I for the 5- and 10-micron sizes, taking viscosity equal to 1.85×10^{-4} poises at 25°C and gravitation equal to 980.5 centimeters per second squared. Since the rate of fall varies as the square of the particle size, the velocity for the 10-micron particle is four times that for the 5-micron. To obtain the air flow in liters per minute, the velocities given are to be multiplied by the area of the settling chamber in square centimeters divided by 1000.

TABLE I

VELOCITY OF FALL OF 5 AND 10 MICRON PARTICLES AGAINST DENSITY CALCULATED FROM STOKES' EQUATION

Density (g./cc.)	Velocity (cm./min.) 5 microns	10 microns
1.0	4.41	17.66
1.5	6.62	26.49
2.0	8.83	35.32
2.5	11.04	44.15
3.0	13.24	52.98
3.5	15.45	61.80
4.0	17.66	70.64
4.5	19.86	79.45
5.0	22.07	88.30
5.5	24.28	97.15
6.0	26.49	105.96

For mixtures of minerals, the density is taken as that of the mean. Thus in any fraction, the heavy particles of maximum size will be smaller than the mean maximum size, and conversely. The difference, however, is not excessive, since the size varies only as the square root of the density; for example, in a mixture of particles of density 3 and 6, the maximum and minimum particle will be 1.2 and 0.8 the theoretical mean.

The end of a fractionation is determined by the end-point, which at present is taken at a rate of separation equal to one-tenth the rate during the first interval. (In ascertaining the initial rate, allowance of ½ to 5 minutes must be made for the time required for the powder to fill the settling chamber.) The time of the first interval is taken at about one-fifth the time to the end-point.

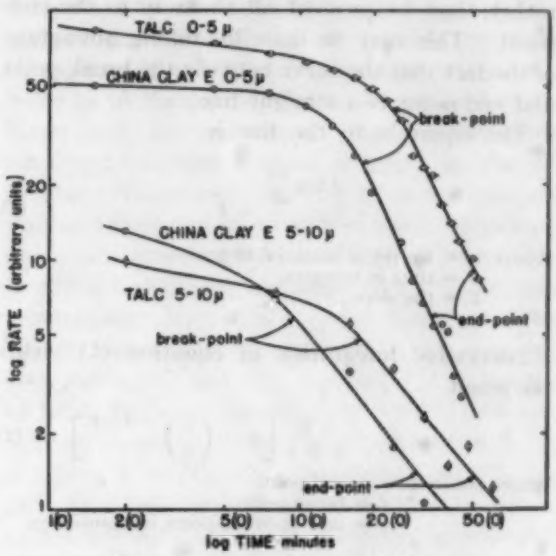

FIG. 1.—Course of fractionation.

The material collected in the thimbles may be checked against the residue by weighing the latter. Between separations on different materials, the largest settling chambers should be freed of their film of dust, preferably by blowing out with compressed air. It is desirable occasionally to check the system for leaks by applying a small pressure.

III. Simplified Determination of the End-Point

When log rate is plotted against log time, characteristic curves such as those shown in Fig. 1 are obtained. A curve of slowly increasing slope is followed rather suddenly by a straight-line curve of steep slope. The end-point of a fractionation, or point at which the particles floating over are largely in the upper

boundary of the fraction[6] lies on this straight line.

As shown in Fig. 1, preceding the end-point is the break-point, which also lies on the straight line but near the origin of the line. The amount of material coming over between the break-point and end-point is small. Consequently, it is often highly desirable, in the case of the finest fraction in particular, to estimate the amount of material lying between these points rather than to proceed all the way to the end-point. This may be done by taking advantage of the fact that the curve between the break-point and end-point is a straight line.

The equation to the line is

$$\frac{d \log \frac{dw}{dt}}{d \log t} = k \qquad (1)$$

Where w = weight of material in grams.
t = time in minutes.
k = the slope.

Successive integration of equation (1) yields the result

$$w_e - w_f = -\frac{t_f r_f}{k+1}\left[1 - \left(\frac{t_f}{t_e}\right)^{-(k+1)}\right] \qquad (2)$$

Where subscript e = end-point.
f = break-point.
r_f = rate at break-point in grams/min.

For the different fractions, the angle of slope ranges from 110° to 125°, but $w_e - w_f$ (as given by equation (2)) is relatively small and insensitive to changes in the substituted value of the angle, so that an average value of k may be used safely.

The short cut provided by equation (2) is generally of interest only in the case of the 0 to 5 micron fractionation, since the other fractions are separated with satisfactory speed. It is found for this fraction that the value of k generally is close to −1.85 (angle 118° or the average of 110° and 125°), so that by substituting this value in equation (2), an equation (3) is obtained.

$$w_e - w_f = \frac{t_f r_f}{0.85}\left[1 - \left(\frac{t_f}{t_e}\right)^{0.85}\right] \qquad (3)$$

By actual test, it is found that the difference in results for the 0 to 5 micron fraction, obtained by using equation (3) and by proceeding to the end-point, is so small that one can not be certain which is the more correct result. By the use of formula (3), about 50% of the total time for the 0 to 5 micron fractionation may be saved, while on the other hand the amount of material involved is only about 15% of the total.

In practice, it is necessary merely to obtain enough points near the break-point to construct a line whose angle of slope is approximately 120°, ascertain the end-point along this line, and substitute in (3) for the evaluation of the weight of material lying between the break-point and the end-point. $\left(\frac{t_f}{t_e}\right)^{0.85}$ may be read off on the plot of $\left(\frac{t_f}{t_e}\right)^{0.85}$ against $\frac{t_f}{t_e}$, which is a straight line on log-log paper.

In working to the break-point only, experience has shown that it is especially important that the jet pressure in the 5 to 10 micron fraction be about the same as for the 0 to 5 micron fraction, or 1.0 to 1.5 inches of Hg. This is necessary in order to scrub out the residual fines effectively.

Where fractions are desired for purpose of examination, mineralogic analyses, or experimentation it is desirable to operate up to the end-point.

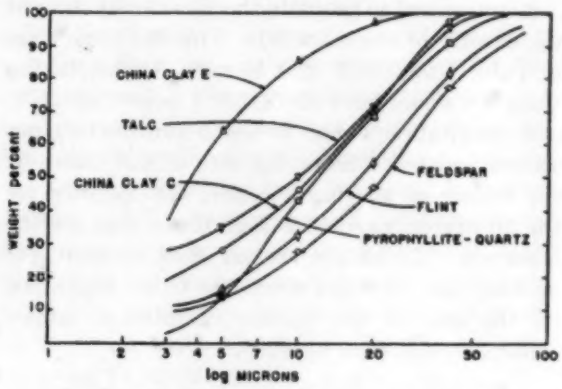

FIG. 2.—Size distribution of ceramic materials.

The difference, however, between this procedure and that of operating only to the break-point is not as great as might be imagined, since the particle sizes along the straight line approach the boundary size in magnitude.

IV. Particle-Size Analyses of Ceramic Materials

Table II gives the size distribution of typical ceramic materials, as determined by the particle-size air analyzer described above.[7] The results are plotted in Fig. 2 as the cumulative weight percentage against log size in microns.

[7] The analyses were made by M. Halwer, scientific aid of this Station, to whom acknowledgment is made.

TABLE II
SIZE DISTRIBUTION OF CERAMIC MATERIALS

Fraction (microns)	Pyrophyllite	Feldspar	Flint	Talc	China clay C	China clay E
	% by weight					
0–5	13.4	14.1	15.9	34.7	28.5	64.1
5–10	29.7	13.4	16.7	15.6	18.1	21.4
10–20	25.4	19.8	21.7	21.4	24.5	11.6
20–40	22.6	30.0	27.4	23.4	26.0	3.0
>40	8.8	22.7	18.2	4.8	3.0	

All of the materials were of commercial origin except the pyrophyllite-quartz (pyrophyllite partly sericite?), which was a natural raw material obtained on a field trip. It was completely screened before analysis. The interesting feature of this material is the comparatively low 0 to 5 micron content compared to the 5 to 10 micron content.

In the plot of Fig. 2, the existence of an inflection point is a characteristic property of all the curves save that for china clay E. For this very fine material, the inflection point probably lies between 0 and 5 microns. Talc and china clay C intersect at 20 microns, so that whereas the clay is finer above this size it is coarser below it.

V. Time of Fractionation of Ceramic Materials

As shown in Table III, the greatest time is required for the 0 to 5 micron fractionation. Considering the interval up to the break-point, the time is seen to range between 60 minutes for feldspar to 150 minutes for the finely divided china clay E. The longer period for the latter material conforms to its greater fineness and its softer, more adherent nature.

TABLE III
TIME OF FRACTIONATION OF CERAMIC MATERIALS

Material	0–5μ To break-point (min.)	0–5μ To end-point (min.)	5–10μ To break-point (min.)	5–10μ To end-point (min.)	10–20 μ To end-point (min.)	20–40 μ To end-point (min.)
Feldspar	60	110	12	32	14	9
Flint	70	110	12	28	15	8
China clay C	90	220	12	35	15	5
Talc	130	230	12	25	15	7
Pyrophyllite	140	325	16	20	10	5
China clay E	150	390	12	30	6	

Owing to the large difference in time between the end-point and break-point in the case of the 0 to 5 micron fraction, it is often desirable to stop at the break-point and estimate the remaining amount of material. For the fractions coarser than 0 to 5 microns, the total time involved is so small that it matters little and it is probably desirable to proceed right to the end-point.

VI. Problems of Absolute Accuracy and Precision

Photomicrographs of the fractions obtained from the clay, talc, and feldspar are shown in Fig. 3. The uniformity of the particle sizes and the close delimitation within the Stokes' law limits are strong assurance of the accuracy of the method. In other words, the size distributions recorded represent the actual size distribution accurately and are not related thereto by some unknown factor, such as may be the case when the distribution is derived indirectly.

As a further contribution to this question, china clays C and E,[8] fortunately, had been analyzed as to their 0 to 10 micron content by Mr. Kane and his associates. The method they employed involved shaking a dilute suspension in a tall cylinder and siphoning off at the required time as calculated from Stokes' law. Trisodium phosphate was used as deflocculant. After six or seven siphonings, the supernatant liquid was substantially free of suspended material. The 0 to 10 micron content obtained in this way was 47% for clay C and 85% for clay E. Reference to Table II shows that the sum of the 0 to 5 and 5 to 10 micron fractions obtained with the air analyzer is 46.6% for clay C and 85.5% for clay E. The two direct methods thus check each other satisfactorily. A similar satisfactory check against liquid elutriation with deflocculation had previously been obtained by the writer on powdered tripoli.

It was originally thought[1] that with soft materials an attrition effect existed. This conclusion was based largely on the S-shape of the curve when plotting rate against time. More recent experience, however, has shown that this type of curve is obtained for all materials, but when plotted logarithmically instead of in Cartesian coordinates, the type of curve possessing a straight-line break is always obtained; this is true at least when working with a nozzle pressure of 1.0 to 1.5 inches of Hg. Figure 1 shows that for such soft materials as clay and talc, the straight line obtained in the usual logarithmic plot exhibits no sign of flattening out even at the lowest rate of only 100 to 150 milligrams per hour. With the understanding that the nozzle pressure is limited to the values mentioned, it may be concluded that no attrition occurs even for very soft materials. This conclusion is reinforced by

[8] Clays obtained through the courtesy of L. B. Kane, Ceramics Dept., Rutgers University.

FIG. 3.—Photomicrographs of fractions, ×525.

the good check of the air method against decantation in the case of the soft china clays just discussed.

For deflocculation by the jet to be complete, it appears necessary to pass the powder, if it is lumped, through a 200-mesh screen. In the case of china clay C, the percentage of 0 to 5 microns was too low by 1.7 when the lumped clay was passed through the 20-mesh sieve only. In other words, 20-mesh clay flocculates could not be completely broken down by the jet at the pressure employed, a difficulty which was re-

flected in the low rate of separation compared to that for the same material passed through the 200-mesh sieve.

A slight uncertainty in absolute accuracy exists in the determination of the end-point. As previously pointed out,[5] during a fractionation the finer particles are first floated off, then the medium, and finally the coarser particles essentially in the upper-size boundary of the fraction. The end-point is determined by the condition that the particles lie essentially in or slightly above the upper size limit. Microscopic test and a check against other direct methods have led to the conclusion that the end-point is at a rate equal to one-tenth the rate during the first interval. Naturally there is some uncertainty attached to this value for the end-point, but fortunately the end-point rate is so small that a divergence from the true value affects the final result only little. The value, one-tenth, applies to the fractions ordinarily delimited as above. For a wider range, such as 0 to 10, 0 to 20, or 0 to 40 microns, there are present indications that the value should be less than one-tenth, and in fact close to one-twentieth the rate during the first interval.

In Fig. 3, the talc fractions are seen to contain various shaped particles, including fibrous talc and long-bladed tremolite. Owing to the relatively great length of the latter crystals, it would appear at first sight that the separation was inaccurate insofar as these are concerned. Actually, however, the long narrow particles appear to satisfy Stokes' equation tolerably well if all three dimensions are considered, and in particular, if the size, d, is defined by

$$\frac{1}{d} = \frac{1}{3}\left(\frac{1}{a} + \frac{1}{b} + \frac{1}{c}\right)$$

Where a, b, and c = the three dimensions.

This definition of the size is logical as it measures the ratio of the surface to the volume of the particle. This point has been discussed previously in some detail,[1] but further experimental work along this line is desirable and is being carried out.

In considering the precision of the results, numerous check tests have shown that the percentages obtained at present can ordinarily be duplicated to less than 0.5%. Refinements to be considered in this direction have to do with constancy of weight of the paper thimbles and adherence of dust to the settling tubes. Because of the difference in temperature and humidity of the air in the room and of the air passing through and near the paper thimble when mounted on the apparatus, the weight of the thimble may change by as much as 30 to 50 milligrams. This source of error has been overcome to a large extent by a final weighing of the thimbles some 20 or 30 minutes after removal from the apparatus.

The expedients adopted to overcome the dust adherence, which is a problem only with the largest tube 9 inches in size, have been the use of sheet stainless steel settling chambers highly polished on the inside, electrical grounding of these tubes, filtering and dehumidifying the air as discussed under Procedure (Section II (3) p. 169), and flushing the tubes preferably with compressed air after each complete analysis. Traxler and Baum[6] have shown that adherence is reduced materially if the tubes are uniformly a few degrees warmer than the air inside. Justification for this conclusion may be found in the early observations of Aitken[9] to the effect that cold particles are repelled from a hot surface. In this work, the desired result was substantially obtained by mounting the motor inside the cabinet that houses the apparatus. Under the above conditions the losses in the present work with ceramic materials ranged in the 0 to 5 micron fractionation from 150 milligrams for flint to 250 milligrams for the clays. Talc, however, showed a loss of 450 milligrams due, probably, to its soft, sticky nature. With the smaller settling tubes the losses were considerably less and practically negligible. In view of the fact that the adhering film of dust under the microscope appears to be made up largely of particles in the boundary range too large to float off and too small to fall readily, the loss due to adherence can be fairly accurately corrected for. It is the practice in these laboratories to assign two-thirds of the loss to the fraction separated and one-third to the next coarser fraction. Since the loss is small and fairly constant for any one material, it seems permissible to assume the loss to be a constant or a small constant fraction of the total amount blown over. By this procedure, it is possible to avoid the need of weighing the

[9] John Aitken, "On the Formation of Small Clear Spaces in Dusty Air," *Trans. Roy. Soc. Edinburgh*, 32, 239–72 (1884).

residue against the total amount of fraction received.

VII. Properties of the Size Fractions

It may be of interest to record some of the properties of the fractions obtained. Where more than one mineral is present one of the mixed minerals is frequently concentrated either among the fine or the coarse particles. The mineral content of the different-size fractions for the pyrophyllite and the talc which contained tremolite is shown in Table IV.[10] The percentage of the softer minerals, pyrophyllite and talc, is seen to increase regularly with decrease in the size of the fractions. The unequal mineral distribution is of course much larger than can be ascribed to any effect of difference in density.

TABLE IV

MINERAL DISTRIBUTION BY SIZE FOR PYROPHYLLITE AND TALC (CONTAINING TREMOLITE)

Fraction (microns)	Pyrophyllite (% by weight)	Talc
0– 5	75	95
5–10	60	75
10–20	34	50
20–40	1	40
>40	5	20

Often the fractions exhibit a difference in hue, if not of color.

The dry bulking of the different fractions has previously been reported.[11]

In general, the 0 to 5 micron fraction exhibits the presence of numerous tight, grainy floccules, while the 5 to 10 micron fraction exhibits fewer floccules, which are softer and less coherent. The 10 to 20 micron fraction has physical properties between that of the 5 to 10 and 20 to 40 micron, the latter exhibiting the appearance of a very fine sand. These properties are subject to variation due to the nature of the material.

When the 0 to 5 micron or more particularly the 0 to 10 micron content has been removed, the residual powder is much more free-flowing. The numerous fine particles seem to act as adhesive friction centers which retard the free motion of the other particles. This observation leads to the belief that the dedusting of pulverized material, by improving its flow properties, would render it more amenable to various treatments, such as magnetic or electrostatic concentration.

[10] The determinations were made by A. Gabriel, petrographer at this Station.

[11] P. S. Roller, "Bulking Properties of Microscopic Particles," *Ind. Eng. Chem.*, **22**, 1206–1208 (1930); *Ceram. Abs.*, **10** [7] 524 (1931).

VIII. Control of Grinding

In the control of grinding operations, it is usually unnecessary to have a complete size-distribution analysis. The sieve has ordinarily been used for control, but we regard it as much more significant and just as convenient to ascertain the content of the 0 to 5 micron fraction. The 0 to 5 micron content is sensitive to changes in manner or time of grinding. By this method it is determined in one operation. The significance of this fraction as a control lies in the fact that it contains the most active particles and most of the surface area of the powder.

IX. Summary

Advantages of the air-separation method of analysis are noted. Problems which enter into the use of an air jet as deflocculant are discussed, and a fractionating apparatus is described which overcomes the difficulties involved. The essential features of the present apparatus lie primarily in the dynamic relationship between the powder sample and the air jet such that the powder is in constant uniform motion against the force of the jet, and secondarily in the means for baffling the jet before it enters the settling chamber. Construction of the apparatus, method of operation, and operating characteristics are described.

Particle-size analyses beginning with the 0 to 5 micron fraction are given for flint, feldspar, pyrophyllite-quartz, two English china clays, and talc. The size distributions are compared, and the time of fractionation, accuracy, and precision are discussed. Some properties of the size fractions are described, and the use of the instrument in the control of grinding is indicated.

NONMETALLIC MINERALS EXPERIMENT STATION
U. S. BUREAU OF MINES
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May, 1937

16—5

Abrasives

Grinding and polishing of iron and metals. Koch. *Oberflächentech.*, **13** [6] 63–64 (1936).—The technique of honing and equipment for it are described together with examples of honing different machine parts. M.H.

Grinding and polishing of light metals. F. Weiss. *Oberflächentech.*, **12** [12] 151–52 (1935).—W. discusses the technique and principles of the grinding and polishing of light metals. M.H.

Measuring abrasiveness. Henry R. Power. *Products Finishing*, **1** [2] 26 (1936).—Methods of determining the resistance to abrasion of various types of surfaces are described. The abrasive resistance of paints, varnishes, lacquers, and electroplated metals (chromium, zinc, and cadmium) is often determined by means of a blasting operation wherein selected and sized Carborundum grains are impelled against the surface under test until failure results. The weight of the abrasive material necessary to produce failure is taken as the index of abrasive resistance. An impact test, in which a steel ball is directed against the surface under a controlled velocity until the surface is defaced, is also used to measure abrasive resistance. Scratch tests, in which points of SiC, fused alumina, and hardened steel are used, are also sometimes adopted. M.C.S.

Nitrogen absorption during grinding of soft iron. H. J. Wiestes. *Arch. Eisenhüttenwesen*, **9** [10] 525–27 (1936).—It was found through calcining tests and microanalytical determination of nitrogen that the changes of structure appearing in insufficiently polished sections of soft iron are due to the absorption of nitrogen from the air by the surface during grinding and the crushing of the surface layers. M.V.C.

Precision cylindrical grinding. A. D. Meals. *S. A. E. Jour.*, **40** [1] 1–10 (1937).—M. discusses center- and centerless-type grinding operations, requirements as to machine rigidity, and grain and grade of grinding wheels. Various types of machines are illustrated for different production jobs. Charts and curves are given relating production speed to degree of finish and diameter of work for both types of grinding. W.H.B.

BOOK

Technical Surface Knowledge (Technische Oberflaechenkunde). Gustav Schmaltz. Julius Springer, Berlin, 1936. 286 pp., 395 illustrations, 32 tables. Price bound 45.60 Rm. S. deals primarily with the science of surface conditions of technical bodies. The various methods for inspection of surfaces by means of touch and vision (naked eye and microscope) are discussed in detail. S. has developed many new methods. The various degrees of surface roughness produced by cutting, shaving, and grinding and the influence of surface condition upon the mechanical strength of construction materials are also discussed. L.E.Thiess

PATENTS

Abrading apparatus. E. R. Newcomb (Carborundum Co.) and H. R. Stratford (Stratmore Co.). U. S. 2,071,563, Feb. 23, 1937 (May 21, 1934).

Abrading machine. Charles Johnson and J. O. Olsen (Mattison Machine Works). U. S. 2,072,951, March 9, 1937 (Jan. 17, 1934). A machine for surfacing thin work sheets is described.

Abrading tool. W. R. Barclay (United Shoe Machinery Corp.). U. S. 2,072,130, March 2, 1937 (Dec. 4, 1934). Fred Ricks and Ernest Hope (United Shoe Machinery Corp.). U. S. 2,072,129, March 2, 1937 (Dec. 4, 1934).

Abrasive article and method of manufacturing. C. E. Wooddell, F. A. Upper, and C. S. Nelson (Carborundum Co.). U. S. 2,072,146, March 2, 1937 (Sept. 23, 1935). Abrasive grain for use in the manufacture of organic bonded abrasive articles consists of a loose mass of abrasive grains each encapsuled in a film comprising a heat-hardened mixture of crude rubber liquefied solely by heating at about 400 to 450°F and a synthetic resin.

Abrasive disk. Joseph Flatow and John Pullman. U. S. 2,073,739, March 16, 1937 (Oct. 12, 1936). An abrasive disk comprises a flexible disk of hard fiber, an abrasive sheet adhesively mounted on one of the faces of the disk, and porous cloth sheets "vulcanized" into both faces of the disk to lessen breakage of the disk and to prevent parts flying around if breakage should occur.

Abrasive wheel. Edward Van der Pyl (Norton Co.). U. S. 2,072,051, Feb. 23, 1937 (Aug. 12, 1935). A grinding wheel comprises a metal disk integrally united to an annular outside band comprising diamond grain bonded with metal, both the disk and the band including aluminum.

Bonded abrasive article and method of manufacturing. O. L. Mahlman and R. C. Benner (Carborundum Co.). U. S. 2,072,507, March 2, 1937 (July 1, 1931). An abrasive article comprises abrasive grains and bond produced from a dispersion of vulcanizable, previously coagulated rubber in liquid comprising a normally liquid resin.

Centerless grinding machine. A. G. Belden and R. A. Cole (Norton Co.). U. S. 2,073,509, March 9, 1937 (Jan. 23, 1935).

Devices for truing grinding wheels. K. Jung. Brit. 461,223, Feb. 24, 1937 (May 12, 1936).

Diamond embedded abrading tool. F. H. Willey. U. S. 2,074,038, March 16, 1937 (May 29, 1935).

Grinding machinery. F. S. Haas (Cincinnati Grinders, Inc.). U. S. 2,072,814, March 2, 1937 (Jan. 3, 1934).

Grinding machine. H. A. Kremer. U. S. 2,071,882, Feb. 23, 1937 (July 16, 1934). A. W. Wigglesworth (Hill-Clarke Machinery Co.). U. S. 2,074,308, March 16, 1937 (Feb. 3, 1936).

Grinding tool. A. H. Wolf (Papendick, Inc.). U. S. 2,073,861, March 16, 1937 (Dec. 23, 1935). A portable tool for blade-sharpening is described.

Grinding wheel truing attachment. R. A. Cole (Norton Co.). U. S. 2,073,577, March 9, 1937 (July 30, 1935).

Hydraulically operated grinding machine. W. H. Wood (Norton Co). U. S. 2,071,677, Feb. 23, 1937 (Aug. 23, 1934).

Hydraulically operated wheel-feeding mechanism. W. H. Wood (Norton Co.). U. S. 2,073,574, March 9, 1937 (July 16, 1935).

Lapping machine. F. J. Theler, G. V. Johnston, and Willetts Peaslee (Cincinnati Grinders, Inc.). U. S. 2,073,079, March 9, 1937 (July 15, 1932).

Method of making abrasive wheels. Baalis Sanford (Norton Co.). U. S. 2,073,590, March 9, 1937 (Feb. 19, 1935). The method of making an abrasive wheel having a resinoid core and a bonded abrasive rim comprises the steps of molding a preformed, dense, central support therefor of greater thickness and smaller diameter than its final dimensions.

Method of manufacturing abrasive articles. O. L. Mahlman (Carborundum Co.). U. S. 2,071,549, Feb. 23, 1937 (May 19, 1936). The method of making an abrasive-coated article comprises coating abrasive grains with a solid permanently fusible resin capable of becoming infusible by heating with a hardening agent, coating a backing with a heat-hardenable liquid resinous material containing a hardening agent for the permanently fusible resin on the abrasive grains, applying a layer of the coated grains to the resin coat on the backing, and heating the coated backing to cause the resin on the grains to flow into the liquid coating on the backing and to harden the resins.

Polishing machine. Owen Doutt (General Spring Bumper Corp.). U. S. 2,073,786, March 16, 1937 (Nov. 14, 1932). A machine for polishing a longitudinal, substantially sinuous surface of a bumper bar is described.

Segmental grinding wheel. Thure Larsson (Norton Co.). U. S. 2,074,114, March 16, 1937 (April 18, 1935).

Stone-polishing machine. W. G. Cumming (Granite City Tool Co.). U. S. 2,073,400, March 9, 1937 (Feb. 18, 1936).

Track grinder. H. H. Talboys (Nordberg Mfg. Co.). U. S. 2,073,816, March 16, 1937 (Nov. 16, 1935)

Art and Archeology

Buried cultures of the Near East: I. Cyrus H. Gordon. *Asia*, **36**, 28–33 (1936).—G. reviews recent archeological discoveries in Egypt, Palestine, Syria, Iran, and Iraq, with a description of the various types of pottery found. W.D.F.

Craftsmen in the glass industry. W. von Eiff. *Glashütte*, **67** [3] 43–46 (1937).—Artistic handmade glassware made at the Polytechnic School of Stuttgart is discussed. Illustrated. M.V.C.

Drinking glasses, their history in Germany. W. Dexel. *Glashütte*, **66** [50] 839–41 (1936).—D. gives a historical review of German drinking glasses, beginning with the 5th and 6th Centuries. Illustrated. M.V.C.

Glass engraving at Corning Glass Works. Anon. *N. Y. Times*, Feb. 5, 1936.—The production of art glass at Corning is described. M.V.C.

Glazed ware in Egypt, India, and Mesopotamia. A. Lucas. *Jour. Egyptian Archeology*, **22**, 140–60 (Dec., 1936).

Good taste in ceramic art is fundamental. F. H. Rhead. *Pottery, Glass, & Brass Salesman*, **52** [12] 23 (1937).—The various types of pottery decoration, including decalcomanias, prints, solid-color glazes, and the new screen process, are discussed. The trend appears to be away from the decal decorations in view of the fact that ten years ago 85% of the ware was so decorated while today only about 50% is so treated. M.C.S.

Irish glass in the 3rd Century. Anon. *N. Y. Times*, Jan. 8, 1937.—A glass workshop complete with hearths, crucibles, and molds was recently discovered by the Fifth Harvard Archeological Expedition. Almost no pottery was used except a little imported from the Rhine, and it is believed that the inhabitants had not yet developed the art of pottery manufacture. M.V.C.

One hundred eighty years of pioneer work. HENRY MACMAHON. *Jour. Roy. Soc. Arts*, **85** [4382] 10–21 (1936). Founded in 1754 for the encouragement of arts, manufactures, and commerce, the Royal Society of Arts has annually bestowed money prizes, premiums, and gold and silver medals in achieving its aims. In 1758 prizes were awarded to manufacturers of iron, brass, china, and earthenware. By 1848 and 1849 the Society was giving exhibitions of British manufactures and decorative art, culminating in the Great National Exhibition of 1851. In 1923 an annual competition in industrial design was established to stimulate art students and industrial designers in characteristic British designs. In 1935 the Fellows of the Society entirely financed the first public exhibition of British Art in Industry in which exhibitors paid nothing for space, thereby insuring selection of designs without fear or favor. At this 1936 session, an honorary degree was awarded, Designer for Industry (D.I.). Twelve such designers were honored with the new degree on this occasion, the first named being McKnight Kauffer (U. S. A.) for outstanding work in commercial art, book jackets, and illustrations. Keith Murray was named for glass, pottery, and silver, and Harold Stabler, for pottery, enameling, and silver-smithing. M. called this "perhaps the most momentous step the Society has ever taken to improve the status of the industrial designer." K.R.

Roman pottery kilns. ANON. *N. Y. Times*, Jan. 2, 1937.—Two Roman pottery kilns have recently been uncovered in Berkshire County, England. The kilns were moved to the Science Museum at South Kensington, London. See *Ceram. Abs.*, **16** [4] 108 (1937). M.V.C.

BOOK AND BULLETIN

Introduction to Pawnee archeology. W. R. WEDEL. *Smithsonian Inst. Bur. Amer. Ethnology Bull.*, No. 112; reviewed in *Notes & Queries*, **171**, 306 (1936). H.H.S.

Red-Figured Athenian Vases in the Metropolitan Museum. GISELA M. A. RICHTER. **Vol. I**, 296 pp. **Vol. 2**, Illustrations. 83 drawings by Lindsley F. Hall. Yale Univ. Press, New Haven, Conn. Price $40.00. Reviewed in *N. Y. Times*, Feb. 21, 1937.—R. describes the red-figured Athenian vases in the permanent collection of the Museum. The whole subject of Greek painting is admirably illuminated, and the catalogue compilations represent a reference work of great value in the realm of scholarship. The accuracy of the drawings makes them a valuable aid to the student aside from their aesthetic appeal. M.V.C.

PATENTS

Decoration of pottery, glass, etc. B. CAPPER. Brit. 461,011, Feb. 24, 1937 (Aug. 15, 1935).

Designs for:

Bottle. J. H. FUNKEY (Carr-Lowrey Glass Co.), U. S. 103,316, Feb. 23, 1937 (Dec. 21, 1936). U. S. 103,495 and 103,496, March 9, 1937 (Jan. 11, 1937). U. S. 103,774, March 23, 1937 (Feb. 10, 1937). W. R. KOHL (Carr-Lowrey Glass Co.), U. S. 103,785, March 23, 1937 (Feb. 13, 1937). P. G. LLOYD (Carr-Lowrey Glass Co.), U. S. 103,730, March 23, 1937 (Feb. 3, 1937). FRASIER SMITH (Hazel-Atlas Glass Co.), U. S. 103,520, March 9, 1937 (Jan. 16, 1937). J. S. STEELMAN (Whitall Tatum Co.), U. S. 103,792, March 23, 1937 (Feb. 5, 1937).

Bowl. W. C. MCCARTNEY. U. S. 103,578, March 16, 1937 (Jan. 29, 1937). W. R. RUCK (Hazel-Atlas Glass Co.). U. S. 103,599, March 16, 1937 (Dec. 21, 1936).

Ceiling lighting fixture. R. G. COWAN (Pass & Seymour, Inc.). U. S. 103,563, March 16, 1937 (Dec. 17, 1936).

Jar. E. W. FUERST (Owens-Illinois Glass Co.). U. S. 103,721, March 23, 1937 (Jan. 27, 1937).

Jug. A. I. LORENZEN (Owens-Illinois Glass Co.). U. S. 103,731, March 23, 1937 (Feb. 5, 1937).

Tumbler. J. E. SPENCE (Hazel-Atlas Glass Co.). U. S. 103,698, March 23, 1937 (Feb. 8, 1937).

Wastebasket, etc. M. H. CONNOR (Owens-Illinois Can Co.). U. S. 103,712, March 23, 1937 (Jan. 21, 1937).

Cements

Investigation of tripoli: II, Part played by tripoli in cement mortar. A. V. ZNAMENSKIĬ. *Zhur. Priklad. Khim.*, **9** [7] 1247–52 (1936).—Small additions of tripoli influence the properties of cementing materials in proportion to the quantity of particles of the addition, independently of its composition. This fact limits the useful introduction of acid additions during the pozzuolanization of cement. During the hydration of cement, the free lime does not combine with the silica of the addition; the reaction is limited only to the adsorption of the latter and to a mobile equilibrium depending on various factors. The adsorption coefficient varies, depending on the kind of tripoli used; for the kinds used in the investigation the adsorption coefficient had a mean value of 0.6. P.B. & E.S.

Investigations on celite: II–III. Y. SANADA. *Jour. Soc. Chem. Ind. Japan*, **39** [11] 400–401B; [12] 466–67B (1936).—Celite cement can be prepared at 1390 to 1410°C, is quick setting, shows lower strength than ordinary Portland cement, and reacts rapidly with water to form needle crystals of hydrated tricalcium aluminate. F Part I see *Ceram. Abs.*, **16** [1] 6 (1937). M.V.C.

Magnesian Portland cement. I. L. LEFAND AND V. V. SEROV. *Tsement*, **3** [7] 7–18 (1935).—Magnesian Portland cement, possessing a constancy of volume both in standard and accelerated autoclave tests, can be obtained under laboratory and plant conditions. The presence of free magnesia leading to inconstancy of volume can be detected by accelerated autoclave tests for 2 hr. under 14 atm. pressure. If the free lime content of clinker does not exceed 5 to 6%, the cement is inconstant in volume; this can be detected at early periods by the autoclave test The magnesium oxide content in clinker was determined for magnesian Portland cement, constant in volume, by X-ray and autoclave tests up to 11%. The clinker can be burned in a rotary kiln; the volatile matter content of the fuel must not exceed 25 to 30%. Data of output and fuel consumption are similar to those of ordinary Portland

cement production. The cement obtained sets in normal periods with an addition of 2% of gypsum and gives good strength characteristics. The introduction of 30% of hydraulic additions does not retard the setting in early periods. P.B. & E.S.

Rapid method for determining silica in raw cement mixtures. N. I. MEDVED. *Tsement*, **2** [5] 20–21 (1934). P.B. & E.S.

PATENTS

Activated magnesium hydroxide and method of manufacture. H. H. CHESNY (Marine Chemicals Co., Ltd.). U. S. 2,073,398, March 9, 1937 (Dec. 26, 1934).

Apparatus for producing high-strength calcined gypsum. W. S. RANDEL, M. C. DAILEY, AND W. M. MCNEIL (United States Gypsum Co.). U. S. 2,074,937, March 23, 1937 (Aug. 5, 1930; July 5, 1934). In a gypsum-calcining apparatus the combination of a plurality of gypsum steam calciners, a conveyer for receiving calcined gypsum therefrom, a common housing surrounding the calciners and the conveyer, a drier, a furnace producing hot gases, means for passing the gases through the drier, a return duct for gases leaving the drier, and a branch duct leading from the latter to the housing.

Enamel

Copper and copper manganese gray cast iron. L. W. EASTWOOD, A. E. BOUSU, AND C. T. EDDY. *Trans. Amer. Foundrymen's Assn.*, **7** [4] 51–97 (1936).—Copper alone increases hardness, compressive strength, and tensile strength, but has little adverse effect upon the transverse properties. The copper-manganese additions increase hardness, tensile strength, and compressive strength markedly and improve the transverse properties slightly in low alloy compositions; these beneficial effects are equally pronounced in low or high silicon irons cast in green sand or dry sand. Many other effects of copper are reported in detail. A discussion is included. H.E.S.

Critical analysis of some statements and experiments on the adherence of sheet-steel ground coats. J. O. LORD. *Jour. Amer. Ceram. Soc.*, **20** [4] 111–14 (1937). **Discussion.** KARL KAUTZ. *Ibid.*, pp. 115–20. **Reply to Kautz discussion.** J. O. LORD. *Ibid.*, pp. 120–21. **Discussion of Lord and Kautz papers.** HOMER F. STALEY. *Ibid.*, pp. 121–24. **Discussion of Staley paper.** R. M. KING. *Ibid.*, pp. 124–25. J. O. LORD. *Ibid.*, p. 125.

Dependence of enamel strength on its working. ANON. *Glashütte*, **67** [3] 49–51; [4] 65–66 (1937).—It was found that (1) the fineness of clay should be greater than that of the frit on grinding; (2) the strength of enamel ground too long can be improved by shorter aging and more rapid drying; and (3) the residue on sifting with a 3600 screen is a measure for the correctness of the working of enamel and hence greater attention should be given to this test. The difference between the loss on calcining and loss on drying (at 105°) yields a factor from which conclusions can be drawn as to the working of wet enamel. M.V.C.

Enamel frit manufacture improved by continuous smelting. THEO. R. OLIVE. *Chem. & Met. Eng.*, **43** [12] 642 (1936).—Through the installation of a continuous frit smelting process and automatic raw materials handling equipment, numerous improvements in the operation have resulted. More definite control of the smelting time and temperature is possible, and frits having greater uniformity of properties and color, better gloss, and higher opacity are produced. These improvements are the result of better smelting due to improved control. M.C.S.

Enamel as a protection from heat rays. VIELHABER. *Emailwaren-Ind.*, **14** [2] 10–11 (1937).—The importance of enamel as a thermal insulating material, especially in enameled houses, is discussed. M.V.C.

Enameled water spouts. VIELHABER. *Emailwaren-Ind.*, **13** [49] 394–95 (1936).—V. discusses the use of water spouts made of cast-iron pipes and enameled with colored enamel instead of zinc-plated water spouts. M.V.C.

Enamels of Pleischl. VIELHABER. *Emailwaren-Ind.*, **14** [1] 2–3 (1937).—The composition of enamel used by the Austrian, Pleischl (1787 to 1867), is discussed. M.V.C.

Factors affecting the structure and properties of gray cast iron. A. DIGIULIO AND A. E. WHITE. *Trans. Amer. Foundrymen's Assn.*, **7** [3] 531–72 (1936).—The effect of superheating cast iron of the unalloyed automotive-cylinder type was investigated by heating the metal to 3110°F. The beneficial effects of superheating were apparent at temperatures near 2700°F and increased with temperature up to a maximum at about 3040°F. The effect of pouring temperature on various cast irons was also investigated. An optimum range for pouring was established between 2680 and 2850°F. Better physical properties obtained through superheating and by pouring at the proper temperature are ascribed to a refinement of the graphite flakes. Specifically, the improvement in physical properties is due to the fact that, under proper conditions of melting and casting, the graphite flakes of the material of the charge are entirely dissolved. Evidence is furnished which proves that graphite will not pass into solution at the eutectic temperature, but will persist as such in the melt, as revealed by quenching molten cast iron in water. A discussion is included. H.E.S.

Grinding of enamel. VIELHABER. *Emailwaren-Ind.*, **14** [2] 9–10 (1937).—Directions for preparing enamel for grinding are given, and the process of grinding is analyzed. M.V.C.

Ground enamel on cast iron for majolica enamels. VIELHABER. *Emailwaren-Ind.*, **13** [50] 403–404 (1936).—V. discusses the production of white ground coats over cast iron for majolica enamels and the difficulties of manufacturing them. Several batches of lead and leadless ground enamel are analyzed. M.V.C.

Interchangeable materials in enamels. VIELHABER. *Emailwaren-Ind.*, **14** [4] 27–28 (1937).—Attempts to substitute some materials for others, *e.g.*, barium carbonate for lead oxide, etc., are dealt with. M.V.C.

Leadless majolica enamels. HEINRICH KIRST. *Glashütte*, **66** [49] 828–30 (1936).—It is possible to replace lead by boric acid with zinc oxide and barium. The fusibility is always somewhat lower and the increase in viscosity is not a disadvantage. An intermediate layer may often be avoided and one firing is eliminated. The

resistance to humidity of leadless majolica enamel is greater, and changes in the color tones and unsatisfactory colors seldom occur. The powder method is preferable and the surface obtained is smoother. Another great advantage is the absence of poisonous effects on the workmen. The disadvantages are that this enamel is less elastic and cracks appear more often; a high-quality cast iron and greater care during enameling are required. Several batches are analyzed and recipes for obtaining wine red, moss green, Bordeaux red, stone gray, and dark brown are discussed. The fusing must always be done in an oxidizing medium. The working and preparation of this enamel are briefly discussed. M.V.C.

Recommendations of the A.F.A. Committee on Chemical Classification of Foundry Steels. ANON. *Trans. Amer. Foundrymen's Assn.*, **7** [3] 581–83 (1936).—This report is submitted to aid in the standardization of designations which might be used for the various steels for castings. H.E.S.

Reusing waste enamel. H. HADWIGER. *Glashütte*, **66** [49] 841–44 (1936).—The sorting of waste enamel is absolutely necessary, and precautions should be taken so that the least possible amount of enamel is wasted. Homogeneous waste enamel in definite amounts can be remelted with the corresponding batch without injury to the enamel. Mixed waste enamel can be introduced into a new batch as a raw material (depending on its composition); in this way the loss of enamel may be reduced to a minimum. Several enamel batches are analyzed. M.V.C.

Rôle of boric acid in enamel. RICHARD ALDINGER. *Glashütte*, **67** [5] 76–78 (1937).—The effect of boric acid in enamel is discussed; it was found that only to a small extent can it be replaced by other enamel raw materials. The best results were achieved when the boric acid content was lowered and powdered glass was used instead of quartz. It is shown by two examples how this replacement can be made. M.V.C.

Specifications for enameled cooking vessels. R. ALDINGER. *Keram. Rundschau*, **43** [41] 481–83; [42] 498 (1935).—Actually, appearance is given less consideration than good behavior during use. Durability depends mainly on resistance against temperature changes, chemical attacks by liquids, and shock. The two first conditions are easy to fulfill, but shock resistance requires a different composition of enamel. It is advisable to use enamel with small expansion for the inner part, the outer part having a higher coefficient. Sheet iron of sufficient thickness is necessary; for vessels of 35-cm. diameter, thicknesses of 0.8 to 1.5 mm. are permissible. Refractoriness and shock resistance of ground coats are superior, but chemical resistance requires cover coat, dark outside, and white for the inner surface. F.E.V.

PATENTS

Enameled metal wall construction. WILLIAM HOGENSON (Chicago Vitreous Enamel Product Co.). U. S. 2,072,882, March 9, 1937 (Aug. 30, 1934). U. S. 2,072,883, March 9, 1937 (Aug. 9, 1935).

Enameled metal wall corner construction. WILLIAM HOGENSON (Chicago Vitreous Enamel Product Co.). U. S. 2,072,884 and 2,072,885, March 9, 1937 (Aug. 9, 1935).

Enamelware utensil. HERBERT DEAN (Federal Enameling & Stamping Co.). U. S. 2,071,817, Feb. 23, 1937 (July 10, 1934). The method of making enamelware cooking vessels comprises applying a base coating of enamel-forming material uniformly over the entire surface of a thin metal vessel, firing the metal to mature the base coating, thereafter applying an additional coating of enamel-forming material over the entire vessel inside and out, drying the additional coating material; thereafter wiping the additional coating material off the main portion of the bottom of the vessel both inside and outside of the vessel, rendering the surfaces so wiped entirely free of the additional coating material, and again firing the ware to mature the additional coating material remaining on the sides of the vessel.

Method of enameling. C. J. RODMAN. U. S. 2,071,765, Feb. 23, 1937 (March 13, 1935). In a method of enameling metal ware, the steps include applying thereto a coating of a frit composed largely of cobalt oxide, heating the ware so coated to a temperature below that required for enameling yet sufficient to cause a superficial filming of the frit, *i.e.*, to between 800° and 1000°F, then applying a color coating of enamel, and heating the ware so coated to the enameling temperature.

Glass

Batching glass electrically. ANON. *Chem. & Met. Eng.*, **43** [11] 596 (1936).—In the construction of a new plant, higher efficiency and less loss can be gained through the proper use of electric conveyers and elevators. The raw materials are unloaded from the box cars with power shovels. In making up the various glass batches, electrically controlled batchers are used to insure accuracy. In addition to more accurate batching, there is a saving of approximately 60% in labor in this one operation. M.C.S.

Beer conduit pipes from glass. THEO ZIENER. *Sprechsaal*, **69** [40] 581–85 (1936).—Z. discusses the suitability of glass conduit pipes in the beer industry, with special regard to the strength, tensile strength, and shaping and cleaning of glass pipes. Illustrated. See "Osram—" *Ceram. Abs.*, **16** [4] 114 (1937). M.V.C.

Carbon yellow glass free from bubbles? K. O. O. HAHNEL. *Sprechsaal*, **69** [20] 284–85 (1936); translated in *Glass*, **13** [6] 252 (1936).—Scientists explain the causes of bubbles as follows: The stabilizer of every yellow coloring from sulfide and its compounds, *viz.*, carbon, which through its reducing capacity should protect the sulfide as coloring agent from the action of free and combined oxygen, is burned like the sulfide by the oxygen and enters into the yellow glass as bubbles. The many factors which must be closely controlled include furnace construction, type of pot, melting time, temperatures of founding and working, the proper viscosities of the glass at each stage of the operation, and the sulfur content of the heating gases in relation to the furnace construction. M.V.C. + M.C.S.

Colorimetric design of red signal glasses. ROGER S. ESTEY. *Glass Ind.*, **17** [12] 409–11 (1936).—Red signal

glass has two desirable properties from a ultilitarian viewpoint, *viz.*, intense redness for distinctiveness and a high light transmission for brilliance and efficiency. S. describes the color and light transmission of red glasses in colorimetric terms and interprets these in terms of spectrophotometric curves so that the best compromise of these desirable properties can be obtained. A description of any color in terms of dominant wave-length and colorimetric purity is immediately comprehensible. E.J.V.

Confused ideas in technical expressions. ANON. *Glashütte*, **67** [2] 19–20 (1937).—Some technical expressions used in the glass industry are discussed with regard to the confusion in their meaning. M.V.C.

Convex glass. ANON. *Glass Ind.*, **18** [2] 48–50 (1937).—The background and history of the L. J. Houze Convex Glass Co. is presented. Methods of producing white opal flat glass from mouth-blown cylinders and goggle balls to be cut up into panes for goggles are illustrated and described. E.J.V.

Design of double-glass hermetically sealed air space. CHARLES D. HAVEN. *Refrig. Eng.*, **30**, 2, 84, 106, 112, 114 (1935); abstracted in *Sprechsaal*, **69** [5] 63 (1936). M.V.C.

Effect of composition of glass on the size of the boundary potential: glass-aqueous solution of electrolyte. K. S. EVSTROP'EV AND N. V. SUIKOVSKAYA. *Compt. Rend. Acad. Sci. U.R.S.S.*, **4** [8–9] 421–24 (in German pp. 424–27) (1934).—The influence of cations (Na, Li, Ba, etc.) can be explained by adsorption processes taking place on the glass surface. It is usually expressed at small p_H values, *i.e.*, in neutral and alkaline regions. See "Glass composition—" *Ceram. Abs.*, **14** [1] 8 (1935). P.B. & E.S.

Effect of properties of glass hollow ware on its strength. K. H. BORCHARD. *Glastech. Ber.*, **12** [10] 334–39 (1934).—The results of studies of Gehlhoff and Thomas (*Ceram. Abs.*, **5** [6] 178 (1926)) are confirmed through the measurement of the strength of bottles. Strength values of handmade Roirant and Owen bottles differ little. Strength values of two bottles are inversely porportional to their diameter, provided that all their other properties are similar and that their profiles are geometrically similar. Strong local strains from cooling endanger strength; uniform strains are usually harmless and even increase the resistance of glass. M.V.C.

Effect of thickness on color of red signal glasses. ROGER S. ESTEY. *Glass Ind.*, **18** [1] 21–23 (1937).—The effect of thickness or concentration of coloring material on the color of a glass sample is shown by data obtained in spectrophotometric studies of typical red glasses. A correlation of thickness with hue and light transmission is also given. E.J.V.

Experiments on radial cracks produced by percussion upon glass plate with initial thermal strain. T. TERADA AND R. YAMAMOTO. *Science Repts. Tôhoku Imp. Univ., Series 1, Honda Anniversary Vol.*, pp. 57–63 (Oct., 1936).—A system of radial percussion cracks was produced upon a glass plate near areas of local thermal strain produced by a gas flame or liquid air. The heated spot "absorbed" the rays while the cooled spot "emitted" the rays. Cracks crossing the boundary between hot and cold regions were "refracted." W.D.F.

Fashioning glass and plate glass. ANON. *Verre & Silicates Ind.*, **7** [36] 432 (1936).—The small electric hand instrument (firm of Bosch) for drilling, grinding, and all other operations in the working and decorating of plate glass and ceramic ware is described. M.V.C.

Fired-in mirrors for optical work. H. SCHULZ. Translated in *Glass*, **13** [11] 472 (1936); for abstract see "Metal—" *Ceram. Abs.*, **16** [3] 87 (1937). M.C.S.

Fire-polishing thin ware. ANON. *Glass Ind.*, **18** [1] 16 (1937).—The delicate operation of glazing or fire-polishing thin-walled glassware for many years has defied all efforts to mechanize it because the glazing heat approximates the softening point of the wall so closely. The problem has been solved through the development and application of a new principle, which consists of cooling the inside of the ware with closely controlled air jets so that the article holds its shape and does not collapse while the exterior is subjected to the required temperatures, which are above the fusing point. Machines incorporating this principle, continuous in operation, automatic as to temperature control, and gas-fired, are described. E.J.V.

Glass brick replace windows, lower maintenance costs, and reduce condensation in air-conditioned plant. L. DRUCKMANN. *Heating, Piping, & Air Conditioning*, **8** [12] 656 (1936).—Hollow glass brick were used to replace double-paned, wooden-sashed windows in the air-conditioned plant of a Chicago silk manufacturer. These brick have reduced condensation and eliminated air leakage and thus have reduced fuel costs, cut maintenance costs, and facilitated better lighting. Removal of all old windows left 36 openings 9 x 14 ft. These were bricked with glass brick at a cost of $165 per opening. Ordinary double-paned windows would have cost only $140 per opening, but considering their high maintenance cost ($800 every three years for paint alone) the cost difference is negligible. Vertical concave lines on one face and horizontal concave lines on the opposite face of each brick eliminate glare by diffusing the light. This diffusion makes window shades unnecessary and eliminates the use of the electric light which formerly was used when shades were lowered to shut out glare. The method of laying the glass brick is described and illustrated. J.L.G.

Glass composition calculations. A. K. LYLE. *Glass Ind.*, **18** [1] 9–13 (1937).—The calculations involved in glass manufacture are considered under three headings: (1) batch to glass, (2) glass to batch, and (3) corrections for the use of arbitrary amounts of foreign or off-composition cullet. E.J.V

Glass melts with phosphates containing potash. JOHANNES LÖFFLER. *Glastech. Ber.*, **12** [10] 332–33 (1934).—Phosphoric acid has an important rôle in the acceleration of glassmelting with molasses potash when compared to melting with pure potash. This easy melting obtained with molasses potash can also be obtained with "synthetic" molasses potash (a mixture of soda, phosphate, sulfate, and chloride) or with phosphate containing mineral potash. Molasses potash does not contain any other agent which promotes melting except those enumerated above. M.V.C.

Glass pump for circulation of gases against moderate pressures. J. C. BALSBAUGH, R. G. LARSEN, AND D. A.

LYON. *Ind. Eng. Chem.*, **28** [6] 682–83 (1936).—A glass pump capable of forcing air against a pressure of 210 mm. of mercury is described and illustrated. F.G.H.

Gorki glassworks. V. M. TARASOV AND A.V. MALCEV. *Keram. & Steklo*, **10** [12] 4–13 (1934).—A detailed description is given of the operation of the Gorki glassworks, manufacturing glass for the automobile industry on Fourcault machines. M.V.C.

Gray cast iron as material for glass molds. O. BERNHOFEN. *Glastech. Ber.*, **12** [10] 339–45 (1934).—Cast iron has its place as industrial material for glass molds because of its valuable properties and low cost. The assumption that its properties vary widely is wrong. The influence of composition, melting, casting, cooling, and calcining on the structure and properties of cast iron is discussed. In most cases an unalloyed finely granulated cast iron is the most suitable for molds. Through the addition of special elements, the properties of cast iron may be greatly improved. The effect of nickel, chromium, and molybdenum is discussed. Types of highly alloyed chromium and aluminum cast iron possess an excellent thermal resistance but are unsuitable for molds because of the difficulty of working them. The highly alloyed "Silal" or the austenitic kinds of cast iron, such as "Niresist" and "Nicrosilal," have a high thermal resistance and can be easily worked; however, they have never been tested as material for glass molds. M.V.C.

Laminated safety glass. R. H. MCCARROLL. *S. A. E. Jour.*, **40** [1] 11–12 (1937).—M. gives the history of development of laminated glass. At the Ford Co., laminated glass is manufactured from $^1/_8$-in. polished plate with 0.025 in. thick cellulose acetate ribbon. After cementing the ribbon between the glass plates, the edges are made moisture-proof to prevent injury to the cellulose acetate in service. W.H.B.

Making optical glass. MURRAY R. SCOTT. *Glass Ind.*, **17** [12] 420–22 (1936).—S. reviews the general melting procedure and methods of manufacturing control used in making optical glass. The process described has been found to give good results over a long period of time. E.J.V.

Manufacture of mirrors. ANON. *Verre & Silicates Ind.*, **8** [2] 16 (1937).—A step-by-step account of the silvering of a mirror is given. M.V.C.

Measurement of absorption of radiation through transparent media. G. BOZZA AND I. SECCHI. *Chimica & Industria*, **17** [11–12] 687–89 (1935).—Measurements of absorption and reflection coefficients of simple and complex glasses treated in different ways are given in a table. M.H.

Methods of furnace control. ANON. *Glass Ind.*, **17** [12] 413–14 (1936).—Control systems are described in detail. E.J.V.

Nonmetallic chemically resistant materials. V. VOLODIN. *Prom. Organ. Khim.*, **2**, 34–37 (1936); abstracted in *Chem. Zentr.*, **1937**, i, 947.—V. describes the manufacture of chemically resistant materials, such as fused quartz, acid-stable cement, Phaolite, Testolite, Bakelite, etc., in Russia. M.V.C.

Multilayer glass and organic safety glass. WALTER OBST. *Diamant*, **58** [28] 326 (1936).—O. discusses and compares the properties of multilayer silicate glass and organic Plexi safety glass. M.V.C.

Permanent tensile stresses in glass. ANON. *Glass Ind.*, **18** [2] 41–44 (1937).—Accurate methods of determining stresses in glass and the effects of different stresses are described. E.J.V.

Polaroid. EDWIN H. LAND. *S. A. E. Jour.*, **40** [1] 19–21 (1937).—L. reviews the properties and use of polarizing material developed to prevent headlight glare. A discussion weighing alternatives and citing the low transmission efficiency of Polaroid is included. W.H.B.

Recent glass wool developments. E. J. DETGEN. *Amer. Glass Rev.*, **56** [16] 19 (1937).—The United States and Germany appear to be pioneering the fields of development and utilization of glass wool. The most recent development set forth in Germany has been the incorporation of glass wool in window panes. A layer of glass wool, 1 to 5 mm. thick, is placed between two panes of glass cemented together at the edges. Window glass so constructed insulates against both heat and sound and also diffuses the light passing through so that more effective illumination is produced. England and Italy have been slow to perceive the importance of this material with the result that it is used chiefly as a heat insulator. M.C.S.

Substances often designated "organic glasses." PIERRE GILARD AND LEON DUBRUL. *Verre & Silicates Ind.*, **7** [36] 425–27 (1936).—The use of the terms "unbreakable glass" and "flexible glass" to designate the synthetic resins is confusing and misleading and should be avoided before it becomes deeply implanted in the language. Resins of condensation differ from silicate glasses by the existence of a filling substance and especially by an irreversibility which separates them clearly from glass defined as a superfused liquid. Polymerization resins are true glasses in every respect; the degree of polymerization appears and is of the same extent as that of silicate glasses. The name "vitroresins" (synthetic resins) is recommended to distinguish the synthetic resins from glass in the accepted sense; the word "resin" gives the idea of an organic substance; "vitro" indicates the noncrystalline character. The term "irreversible" or "thermohardening vitroresins," distinguishes the resins of condensation from the resins of polymerization which are qualified as "reversible" or "thermoplastic vitroresins." M.V.C.

Temperature dependence of absorption of filter glasses. K. WEBER. *Z. Wiss. Phot.*, **35**, 193–96 (1936); abstracted in *Chem. Zentr.*, **1937**, i, 967.—The permeability of red filter glasses decreases with increasing temperature. M.V.C.

Test for glass tank blocks. E. BAYER. *Keram. Rundschau*, **43** [46] 544–45 (1935).—Aggression of batch is stronger than that of glass, but the destruction of blocks is chiefly due to molten glass. B. describes a test intended to foresee the probable behavior of blocks. A 5-cm. cube is pressed in a crucible for 5 days in presence of glass at 1240 or 1320°C. The characteristics to determine are velocity of solubility, nature of the refractory-glass surface, nature of solubility (homogeneous, cords, stones), saturation of foreign material in glass, and investigation of alumina content. F.E.V.

Will glass silk and glass wool lead to a new development of the glass industry? KARL O. O. HAHNEL. *Sprech-*

saal, **69** [6] 76 (1936).—H. points out the necessity of determining elasticity and other physical properties of the finest glass threads and layers for the development of the glass industry. M.V.C.

BOOKS AND BULLETINS

Floaters in continuous glass tanks. H. HAUSNER. *Fachausschussber.* (Deut. Glastech. Ges.), No. 15, 7 pp. (1929).—H. deals with (1) the usual forms and dimensions of floaters, (2) new forms adapted to glass depth, (3) influence of immersion on glass flow, and (4) properties required from refractory material. H. describes results of his experiments and discusses the height of floaters. Immersion must be adapted to the cross-section of glass flow. This flow is deeper in the center. The quality of glass and efficiency of the tank depend largely on the dimensions of floaters. As raw materials, acidic clays and fine grog are preferred, firing as high as possible (1300° to 1350°C). The transport of floaters is difficult. Fine-grained bodies do not withstand successive firings. F.E.V.

Fundamentals of Production of Optical Glass. N. N. KACHALOV AND V. G. VOANO. ONTI, Khimteoret, Leningrad, 1936. 194 pp. The first part of this book is devoted to the physicochemical properties of glass, especially optical properties. The technological process of production of optical glass, including questions of raw materials, refractories, and furnaces, is given in the second part of the book. P.B. & E.S.

Glass industry in Italy. CORRADO ROVINI. Stabilimento-Grafico Fratelli Lega, Faenza. 27 pp. Reviewed in *Verre & Silicates Ind.*, **8** [2] 22 (1937).—R. gives a history of glassmaking in Italy and a description of the present situation. From the Roman period, the vase of Naples, the Barberini (Portland) and Strasbourg vases, diatrètes ornamented with fretwork, and some mirrors have been preserved. The Byzantine glass industry was established in 976 at Venice and its greatest period extended from the 15th to the 16th Centuries. The manufacture of spectacle glass has been regulated since 1301. The decadence of Murano was complete by the 19th Century. Florence and Altare developed independently. Modern manufacture in Italy is relatively backward, and there are three plants that still produce mouth-blown glass (Tuscany). The mechanical processes, deposits of raw materials, and economic state of the industry at present are described. M.V.C.

Safety glass, a national problem. (Sicherheitsglas, ein Volkwirtschaftliches Problem). A. SULFRIAN AND H. KINON. Reviewed in *Glashütte*, **67** [4] 67 (1937).—The first part of the booklet, written by S., deals with various kinds of safety glass, their requirements, and their testing. The second part, written by H. Kinon, is devoted to the development of the safety glass industry, the manufacture of safety glass, and the manufacture of multilayer glass, its testing, and its use in aviation. M.V.C.

Transmission of light through window glasses. ANON. *Dept. Sci. Ind. Research, Illumination Research, Tech. Paper*, No. 18 (1936). H. M. Stationery Office, London. 18 pp., 48 illustrations, 9 figs. The transmission factors of forty-nine kinds of window glass have been measured under three conditions as to the distribution of the incident light, *viz.*, (1) direct light incident normally on the glass, (2) completely diffused light, and (3) light restricted to angles of incidence between 45 and 90°. The values of the transmission factor found for normally incident light vary from 92 to 65% (excluding a glass designed to absorb infra-red), while for obliquely incident diffused light the transmission factor of a number of glasses falls to about 50%. The concealing power of many of the glasses is shown by means of photographs of a black and white checker pattern placed behind the various samples. A description is given of some tests made to determine the loss of transmission due to gradual accumulation of dirt, and the conclusions for the long-period tests (18 months) are (*a*) that the loss of transmission is most rapid during the first three months or so after cleaning, and (*b*) that the rate of dirtying is not appreciably affected by the nature of the surface of the glass, so long as the rough surface, if any, is on the inside of the window. The conclusions for the short-period tests (6 weeks) are (*a*) vertical windows in Westminster at ground level dirty twice as fast in winter as in summer; (*b*) the rate of dirtying is appreciably greater for ground-floor windows than for windows on upper floors; for the latter, the winter rate of dirtying is about 1 to 3 times the summer rate; and (*c*) the loss of transmission during a period of six weeks is always less than 10% of the transmission of the glass when clean. H.E.S.

PATENTS

Apparatus for detecting strain in diffusive glass. S. M. GRAY (Electrical Testing Laboratories). U. S. 2,073,691, March 16, 1937 (Aug. 15, 1935).

Apparatus for detecting strain in glass of a partially diffusing character. S. M. GRAY (Electrical Testing Laboratories). U. S. 2,073,690, March 16, 1937 (April 22, 1932). An apparatus for visually detecting strain in glass having a surface or film of a light-diffusing character comprises a source of light, optical means for directing rays from the source in the form of a nondiffused beam of light, a polarizer to which the beam is incident, and an analyzer adapted for movement into either of two operative positions corresponding to which the lines of vision respectively established are in and out of the path of the polarized light proceeding from the polarizer, the source being of sufficiently high intensity to cause a substantial quantity of substantially undiffused rays to pass through the light-diffusing surface of light-diffusing film portion of the specimen undergoing test in the path and on either of the lines of vision, the polarizer and analyzer for either of the analyzer positions having their respective planes of polarization to light at right angles to one another.

Article-transferring mechanism. C. S. RILEY (Hartford-Empire Co.). U. S. 2,072,826, March 2, 1937 (June 5, 1935).

Banding machine. H. R. SCHUTZ (Libbey Glass Co.). U. S. 20,277, Feb. 23, 1937 (March 19, 1935); reissue of original U. S. 1,985,800, Dec. 25, 1934.

Coffee-making device. F. E. WOLCOTT (Silex Co.). U. S. 2,072,935, March 9, 1937 (Sept. 30, 1935).

Dispensing bowl. F. E. WOLCOTT (Silex Co.). U. S. 2,072,934, March 9, 1937 (April 29, 1935).

Electric furnace for melting glass. JAKOB REGENS-

TREIF AND OTTOKAR SORGE (Patent-Treuhand-Ges. für Elektrische Glühlampen m. b. H.). U. S. 2,071,707, Feb. 23, 1937 (Feb. 26, 1935). In an electric glassmelting furnace an electrode comprises a conductive body having means for supplying a cooling fluid thereto, the means being constructed so that the distance between the active surface of the electrode making contact with the body of glass and the portions of the supply of fluid is increased from the bottom part toward the top part of the electrode.

Feeding molten glass. K. E. PEILER (Hartford-Empire Co.). U. S. 2,073,572, March 9, 1937 (March 10, 1914). An apparatus for feeding molten glass for mold charges comprises a heated chamber, means for flowing, suspending, and accumulating masses of the glass in the chamber, and severing means movable into and out of the chamber.

Glass-annealing leer. CARROLL CONE (Surface Combustion Corp). U. S. 2,074,252, March 16, 1937 (July 29, 1936).

Glass-feeding mechanism. T. C. STEIMER (Hartford-Empire Co.). U. S. 2,073,573, March 9, 1937 (Feb. 12, 1910; Oct. 27, 1925).

Glassforming machines. UNITED GLASS BOTTLE MANUFACTURERS, LTD., AND T. C. MOORSHEAD. Brit. 461,133, Feb. 24, 1937 (Sept. 17, 1935).

Glass goblet stem-forming tool. L. W. GAMES. U. S. 2,074,784, March 23, 1937 (Oct. 29, 1935).

Glass-transfer mechanism. G. R. HAUB (Hazel-Atlas Glass Co.). U. S. 2,072,502, March 2, 1937 (June 18, 1935).

Glassworking apparatus. T. C. STEIMER (Hartford-Empire Co.). U. S. 2,073,571, March 9, 1937 (Feb. 12, 1910). An apparatus for separating molten glass into mold charges is described.

Heat-resisting fluoride borosilicate glass. H. P. HOOD (Corning Glass Works). U. S. 2,072,207, March 2, 1937 (March 19, 1934). A transparent heat-resisting borosilicate glass contains fluorine and chlorine and between 80 and 90% of silica.

Insulator and method of making. C. H. DIBBLE (Corning Glass Works). U. S. 2,072,201, March 2, 1937 (July 28, 1933).

Laminated glass. E. L. FIX AND B. J. DENNISON (Duplate Corp.). U. S. 2,072,583, March 2, 1937 (Feb. 17, 1934). A laminated plate comprises a pair of glass sheets cemented to the opposite sides of a sheet of cellulose plastic with a cement comprising a solution including water, cellulose derivative similar in composition to the plastic sheet, a solvent for the cellulose derivative, and one of the alkaline metal salts following: *X*-stannate, *X*-citrate, *X*-phosphate, *X*-arsenate, *X*-oxalate, *X*-bromide, *X*-molybdate, *X*-silicate, *X*-tungstate, *X*-aluminate, *X*-chromate, *X*-antimonate, *X*-permanganate, and *X*-vanadate, wherein *X* represents one of the alkaline metals.

Laminated glass, etc. A. KÄMPFER. Brit. 461,201, Feb. 24, 1937 (April 12, 1935).

Laminated safety glass. W. J. ARNER AND R. W. WAMPLER (Libbey-Owens-Ford Glass Co.). U. S. 2,071,377, Feb. 23, 1937 (June 28, 1934). The process of producing an adhesive for the manufacture of transparent laminated safety glass comprising two sheets of glass and an interposed adherent layer of cellulose acetate plastic includes the steps of forming a reaction product by treating cellulose acetate with a mixture of hydrochloric acid and orthophosphoric acid and then dissolving it in a plasticizer therefor.

Method and apparatus for feeding molten glass. G. E. ROWE (Hartford-Empire Co.). U. S. 2,072,827, March 2, 1937 (Aug. 18, 1934).

Method of forming canals in glassware. C. G. ANASTOR (Kimble Glass Co.). U. S. 2,072,194, March 2, 1937 (Oct. 31, 1934).

Method and mold for casting glass. A. B. REDMAN (T. C. Wheaton Co.). U S 2,073,254, March 9, 1937 (April 19, 1935).

Multifocal lens. EDWARD CULVER AND S. A. EMERSON (United Kingdom Optical Co.). U. S. 2,071,616, Feb. 23, 1937 (Nov. 9, 1934).

Ophthalmic lens. H. W. HILL (American Optical Co.). U. S. 2,072,593, March 2, 1937 (Nov. 24, 1930; renewed March 25, 1936).

Ophthalmic lens and method of making. E. J. REH (Bausch & Lomb Optical Co.). U. S. 2,074,072, March 16, 1937 (Feb. 1, 1935).

Surfacing machine for plate glass. H. S. HEICHERT (Pittsburgh Plate Glass Co.). U. S. 2,074,111, March 16, 1937 (June 23, 1936).

Structural Clay Products

Change in physicomechanical properties of construction brick from marl clays under the influence of moisture. I. YA. SLOBODYANIK AND T. N. RUNSKAYA. *Stroitel. Materialy*, No. 8–9, pp. 37–40 (1936). P.B. & E.S.

Compressive strength of structural tile masonry. DOUGLAS E. PARSONS AND DAVID WATSTEIN. *Jour. Research Nat. Bur. Standards*, **18** [2] 215–26 (1937); R.P. 972. Price 10¢.—In coöperation with the Housing Div. of the Federal Emergency Administration of Public Works, 6 walls and 30 wallettes were tested. The object was to determine how differences in tile design or kind of mortar affected the compressive strength of masonry walls in a combination of brick-facing and end-construction tile under eccentric loads. The walls were of structural clay tile with a facing of brick, alike in all respects except design of the tile. Different mortars as well as tile of different designs were used to construct the wallettes. All masonry specimens were tested at the age of two months. As the loads were applied on the walls during compressive tests, the rate of deformation increased with increasing loads, because of the yielding of the mortar. The mortar (1 part cement, 1 part lime, and 6 parts sand by volume) crushed in the bed joints of the tile. The strengths of the walls were roughly proportional to the thickness of the face shells of the tile. The crushing of the mortar in the bed joints was the first sign of impending failure of the wallettes, except for those built with mortars rich in Portland cement. R.A.H.

Marketing brick through architects. ANON. *Ind. Marketing*, **21** [9] 26 (1936).—The architectural development program of the Old Virginia Brick Co. is described. Brick and brick houses were studied and their histories

advertised from the standpoint of romance and tradition. It was chiefly through this work that "bottom" and cull brick were first found to be desirable owing to their "born-old" color indicating age. M.C.S.

Multiple causes of tile warping. M. V. *Rev. Matériaux Construction Trav. Publics*, No. 327, pp. 177–78B (1936).—Because of their large surface and relative thinness, tile are especially subject to deformation. V. cites some of the causes of deformation brought about during preparation, at which time the defect is not noticeable. The clay may contain too much lime finely divided in the mass. This condition is remedied by the addition of more refractory clay. Green tile are often sensitive to drafts and heat and should be protected from them. The clay should be properly weathered and worked. Badly adjusted finishing cylinders and presses where there is lateral friction, irregular rate of advancement between the center and upper and lower surfaces, defective position of the drawplate, and too rapid drying cause deformation. Only dry tile should be put in the kiln and the condensation of moist gas on the thin ware should be prevented. M.V.C.

Reinforced brickwork. L. W. Burridge. *Jour. R.I.B.A.*, Jan. 23, 1937; abstracted in *Brit. Clayworker*, **45** [538] 332–35 (1937).—B. gives the history of reinforced brickwork and discusses the factors in structural design. He points out that little information is available upon the depth of cover of the steel necessary to prevent corrosion of the steel. The advantages generally claimed for this type of construction are listed, and the trend of possible development of reinforced brickwork construction is suggested. R.A.H.

Selection and testing of brick for railways. L. G. B. Rock. *Brit. Clayworker*, **45** [538] 346–49 (1937).—R. describes the tests used by a railway for the selection of brick with respect to (1) cost, (2) resistance to weathering, (3) strength, (4) appearance, and (5) uniformity of size. R.A.H.

Use of magnesian lime in production of lime-sand brick. E. D. Pevsner. *Stroitel. Materialy*, No. 8–9, pp. 32–37 (1936).—Magnesian and dolomitic lime with about 34% of lime can be used if the brick is produced from a slightly rammed plastic or semiplastic mass. The use of sand of different size grains permits the water content to be lowered. P.B. & E.S.

PATENTS

Building wall structure. J. C. Garvey and A. A. Kreblin. U. S. 2,073,788, March 16, 1937 (May 17, 1933). A weatherproof building wall structure is described.

Means for manufacturing clay and marl products such as brick, tile, etc. H. Leigh. Brit. 460,695, Feb. 17, 1937 (June 23, 1936).

Nonslip surfaces for paving blocks. F. G. Small. U. S. 2,073,814, March 16, 1937 (Dec. 7, 1932). A paving block has a plurality of integral load-carrying projections of uniform height and a plurality of integral uniformly higher load-carrying projections to constitute abutments to objects sliding on the lower projections, the higher projections being so grouped together that a surface covered by an assembly of the blocks is provided with uniformly distributed groups of the higher projections in staggered relationship.

Refractories

Action of alkalis on refractory materials: V, Further observations on the action of potassium chloride vapor on refractory materials at 1000°C. F. H. Clews and A. T. Green. *Refrac. Materials Joint Comm., Inst. Gas Engrs., 27th Rept.*, pp. 33–41 (1936).—The effects of intensity of previous firing, porosity, and ferric oxide content on the reaction of KCl vapor on refractory specimens are reported. Hard firing materially reduces the amount of attack. In dry air the attack on specimens containing the ferric oxide was slightly less than on those without the addition; thus it appears that there is no catalytic activity of iron oxide in promoting the reaction between clay and potassium chloride at 1000°C. The action of the alkali vapor caused an expansion of the clay specimens, in some cases as high as 3% in length. **VI, Action of vapor of a potash-silica glass on refractory materials at 1200°C.** F. H. Clews, H. M. Richardson, A. Chadeyron, and A. T. Green. *Ibid.*, pp. 42–49.—Test pieces of different refractories were suspended over the surface of molten potash-silica glass maintained at a constant temperature of 1200°C. As with KCl vapor, the more porous materials showed the greater attack. Silica suffered more attack than fire clay. Painting the surface of the specimens with aluminum paint and heating to oxidize the metal formed a protective coating that appreciably reduced attack. Previously exposed brick showed a fairly large volatilization of K_2O when heated in a furnace at 1200°C. For Part IV see *Ceram. Abs.*, **15** [10] 301 (1936). R.F.R.

Application of mullitic refractory products to boilers. Marcel Lépingle. *Chimie & Industrie*, **36** [6] 1087–94 (1936).—The conditions under which extra-aluminous refractory products of the sillimanite type are used in boilers are examined. Laboratory tests and an example from practice are described. The principal defects of certain types of these refractories and their discovery are cited. M.V.C.

Drying cracks in fire brick. C. E. Moore. *Claycraft*, **10** [2] 70 (1936).—The causes of and remedies for the drier cracking of fire brick are discussed. The proper use of grog usually facilitates drying and reduces cracking. Through improved temperature control and heat distribution in the drier, higher temperatures may be carried which result in more rapid and effective drying. Imperfect mixing of the clay and water is sometimes responsible for cracking in the drying stage. M.C.S.

Effect of hydrocarbon gases on refractory materials: II, Further study of the effect of methane on refractory materials. E. Rowden and A. T. Green. *Refrac. Materials Joint Comm., Inst. Gas Engrs., 27th Rept.*, pp. 9–13 (1936).—Pure methane was passed over five specimens of fire brick and two of silica maintained at a temperature of 880°C. After a 30-hr. treatment two firebrick specimens had developed cracks. The first firebrick sample disintegrated after 37½ hr., the second after 44½ hr., and the third after 52 hr.; after 66½ hr., pieces had flaked off the fourth firebrick specimen.

After a total time of 160 hr., of the original seven samples one firebrick and the two silica specimens were still whole and unattacked except for carbon discoloration throughout. Comparing with the results obtained at 795°C (Part I), two important differences were observed: (1) at the higher temperature the discoloring was much more pronounced, in some cases being jet black throughout, and (2) although the time required for disintegration was less at the higher temperature, the amount of disintegration was less. After 67 hr. at 795°C, the four firebrick specimens were mainly reduced to small pieces of about 0.25 in. in size. No action had occurred after 37½ hr. The pieces produced upon disintegration at the higher temperature were much larger, although cracking had commenced at 30 hr. Apparently, the iron spots in the brick are the foci of attack, carbon being deposited at these spots. The black discoloration is removed when the specimens are heated to a red heat in an oxidizing atmosphere. **III, Effect of coal gas on refractory materials.** *Ibid.*, pp. 13–20.—Coal gas, the chief constituents of which are CO 16.7%, CH_4 19.5%, H_2 47%, and unsaturated hydrocarbons 4%, was passed over the firebrick and silica samples. The experiments were carried out at 500°, 800°, and 900°C. Although the specimens were discolored, no cracking or disintegration occurred at 500° or 800°C after 200 hr. After 72 hr. at 900°C, one firebrick specimen had disintegrated while two other firebrick samples showed cracks. After 250 hr., only one firebrick specimen had disintegrated and three had cracks or corners broken off. One firebrick and two silica specimens were still unbroken. Discoloration was of about the same intensity as with methane. The absence of disintegration in the specimens heated at 500°C is noteworthy, since this is within the range of temperature where breakdown due to the action of carbon monoxide may be expected, and the gas used contained carbon monoxide and methane in about equal proportions. For Part I see *Ceram. Abs.*, **15** [10] 301 (1936). R.F.R.

Furnace wall development. Geo. P. Reintjis Co. *Mining Jour.* [Phoenix], **19** [17] 31 (1936).—The Company's standard wall tile have been adapted for use as rear arches on horizontal return tubular boilers. Design is such that each tube is individually hung by an independent casting from a pipe. The advantage of the flat suspended arch is to provide turbulence in the gases so that all of the boiler tubes receive an equal proportion of the hot gases, thereby increasing boiler efficiency. J.M.W.

Further experiments on the behavior of silica mixes on being pressed. F. H. Clews and A. T. Green. *Refrac. Materials Joint Comm., Inst. Gas Engrs., 27th Rept.*, pp. 57–70 (1936).—A previous report (see *Ceram. Abs.*, **15** [10] 302 (1936)) described the behavior of sillimanite mixes on being pressed. This report describes a similar study in connection with silica-brick mixes. Similar results were obtained on (*a*) relation of pressure to density and (*b*) effect of the pressing process in causing an alteration in the proportioning of the grain sizes. The effect of simultaneous pressing from top and bottom was studied to ascertain whether this process reduced the variation in texture from exterior to interior inherent in singly-pressed products. R.F.R.

German raw materials for the preparation of magnesia refractories. A. Berge. *Keram. Rundschau*, **43** [40] 471–73 (1935).—There is a shortage of magnesia, partly due to American consumption of Austrian raw materials. B. proposes to use the wastes of Stassfurt carnallite ($KCl \cdot MgCl_2$) industry. $MgCl_2$ may give arsenic-free HCl. After decomposition, the residue contains 95MgO + 2.2K_2O + 2.8Na_2O. To insure compactness, an addition of 10% kieserite slurry (dry) and 4% silica sand should be made to bind alkalis. The end product has a composition similar to Austrian or Czech magnesia blocks although the fluxes are different; iron oxide and lime are replaced by alkalis and boron oxide. F.E.V.

Hydrogen factor in incomplete combustion. Anon. *Glass Ind.*, **18** [1] 14–16 (1937).—It has been found that as soon as carbon monoxide appears when incomplete combustion conditions exist, hydrogen also appears, except in the case of fuels containing comparatively little hydrogen. The neglect in taking into account the fact that hydrogen does exist in flue gases when carbon monoxide is present has led to serious errors in the calculation of furnace heat losses. Waste-heat loss calculations of glass furnaces in which the loss due to the presence of carbon monoxide only is determined are therefore low. While danger of imperfect combustion of the fuel with the resulting development of hydrogen can be readily seen when heat losses are converted into dollars and cents, it is highly probable that a larger unseen loss, difficult to calculate, can also take place. Hydrogen, more than any other gas, is susceptible to flameless catalytic "surface combustion" when it comes into contact with red-hot brickwork. The intense local heat produced through the surface combustion of hydrogen can be very harmful to the refractory material upon which it is taking place. It is possible that some of the excessive wear of glass-furnace walls, crowns, ports, and the hotter portions of the regenerators may be caused by or accelerated by surface combustion of hydrogen formed when the fuel is being imperfectly burned. As a check against imperfect combustion and the development of hydrogen, a mechanical (density-type) or thermoelectric-type CO_2 recorder may be installed. The chemistry of the formation of hydrogen in imperfect combustion is discussed. E.J.V.

Improvements in refractory materials. P. B. Robinson. *Gas World* [Coking Section], **24** [287] 10–13 (1937).—Improvements in various types of refractories are briefly reviewed, the difficulties experienced in effecting these improvements are discussed, and some of the methods used in the course of development are described. Illustrated. F.G.H.

Influence of the rapidity of firing on the softening temperature under constant load of refractory materials. Leon Scheepers. *Chimie & Industrie*, **36** [6] 1109–13 (1936).—S. describes the equipment and the system of regulating the rate of firing used in tests on different rates of heating. A high-frequency electric furnace of the Ribaut system with 25 kv.-amp. was used, and the apparatus has given satisfaction since 1931. Increasing the rate of heating causes a rising of the softening temperature under load of refractory materials. This action differs according to the nature of the products tested and the chemical composition. The difference in temperature

due to the rate of firing is more noticeable if the temperature of the sides of the test piece is measured with an optic pyrometer instead of the graphite plate above it. The sample should be put in a suitable place in the furnace. M.V.C.

Insulation of open hearths reduces time of heats. G. Soler and E. E. Callinan. *Steel*, **96** [April 15] 62–66 (1935); see *Ceram. Abs.*, **15** [2] 64 (1936). H.E.S.

Jointing cements: V, Behavior of joints under tension and compression. F. H. Clews, H. Booth, H. M. Richardson, and A. T. Green. *Refrac. Materials Joint Comm., Inst. Gas Engrs., 27th Rept.*, pp. 20–31 (1936).—A new apparatus is described whereby the behavior of joints in tension or compression can be studied up to 1400°C. Temperature-deformation curves are presented for a sillimanite-ball clay-sodium silicate cement and various lime- and clay-bonded silica cements heated under different loads. **VI, Note on the permeability of some fired joints.** F. H. Clews, H. M. Richardson, and A. T. Green. *Ibid.*, pp. 31–33.—The air-permeability was measured for a number of cemented and fired joints to assess their gas-tightness under different conditions. For Part IV see *Ceram. Abs.*, **15** [10] 302 (1936); for Parts I–II see *ibid.*, **16** [4] 119 (1937). R.F.R.

Lining of rotary kilns. A. S. Dokudovskiĭ. *Tsement*, **3** [5] 30–37 (1935).—Technical requirements for the different linings used are reviewed with special reference to grog, talc, and clinker-concrete brick. P.B. & E.S.

Manufacture of special refractory products in Belgium. Marcel Lépingle. *Verre & Silicates Ind.*, **7** [36] 428–29 (1936); **8** [1] 1–4; [2] 14–16; [3] 25–28 (1937).—L. examines the present state and evolution of the manufacture of special refractory products in Belgium and describes the classes of products, manufacturing processes, and fields of application. The development of the use of these special super-compressed products, extra-aluminous, magnesia, chromite, spinel, and silicon carbide, and their possibilities are treated. M.V.C.

Open-hearth checkerwork design. George L. Danforth, Jr. *Blast Fur. Steel Plant*, **24** [10] 899; [11] 981–83 (1936).—The more important features to incorporate in the checkerwork design to gain the best over-all results in the regenerator chamber provided are (1) total mass of brickwork for maximum heat storage; (2) maximum brick surface so exposed to the flow of gases as alternately to absorb the greatest possible amount of heat from the hot waste gases and correspondingly to heat the comparatively cold incoming gases; (3) passageways throughout the checkerwork, necessary for a sufficiently free flow of gases, yet so arranged that the gases properly contact the exposed surface of all the brick mass provided; and (4) reasonable cost of maintenance. The common practice used to be to lay 9- x $4^1/_2$- x $2^1/_2$-in. brick on edge and sometimes staggered, but when larger furnaces came into vogue, the $10^1/_2$- x $4^1/_2$- x $4^1/_2$-in. checker block became the standard for use in regenerators. Owing to the lower amount of exposed surface per unit of mass and high heat absorption of the inner mass, it was found that the efficiency would be improved by using $2^1/_2$-in. thick brick instead of $4^1/_2$-in. block. The Danforth checker design and the Danforth-Peterson checkerwork, which was devised to give superior results in either the single-pass or multiple-pass regenerator, are described. Characteristics and properties of the various types of checkerwork are discussed in detail. Illustrated. E.J.V.

Refractoriness-under-load test: IV, Further experiments on the maintained-temperature test. F. H. Clews and A. T. Green. *Refrac. Materials Joint Comm., Inst. Gas Engrs., 27th Rept.*, pp. 49–56 (1936).—An account is given of experiments designed to ascertain the degree of accuracy in a maintained-temperature test. Several sources of error, most of which are quite small, are discussed. For Parts II–III see *Ceram. Abs.*, **15** [10] 303 (1936). R.F.R.

Refractory concrete, a new and remarkable material for kiln building. Anon. *Brit. Clayworker*, **45** [537] 310–12 (1937).—This product is formed by the combination of high-alumina hydraulic cement with various aggregates, providing a range of refractory jointing mortars and concretes with valuable properties. The two important points of difference between Portland and high-alumina cements are the proportions of alumina and lime which each contains. Refractory concrete containing the high-alumina cement may be used up to working temperatures of 1350°C; when mixed with chrome or magnesia as aggregates, it may be used for temperatures up to 1600°C. See *Ceram. Abs.*, **15** [7] 208 (1936). R.A.H.

Refractory materials for the glass industry. Hugo Menzel. *Sprechsaal*, **69** [41] 600–601 (1936).—A brief account is given of a special course on refractories given by the Silesian Glass Technical School at Bunzlau in August, 1936, and of an exhibition of refractories held at the same time. M.V.C.

Slags and gases in cupola operation. A. H. Dierker. *Trans. Amer. Foundrymen's Assn.*, **7** [2] 404–14 (1936).—The theory of combustion in cupola operation is discussed. Belden's work on cupola gases and temperature is reviewed. Oxidizing and reducing conditions and the factors affecting these conditions are discussed in detail. A study of the cupola slags and the question of chemical reactions taking place in the operation of the cupola as a melting unit are presented. A discussion is included. H.E.S.

So-called refractory cements and the first method of preparing really refractory monolithic structures. A. Braniski. *Bul. Chim. Soc. Române Chim.*, **37**, 239–44 (1934); *Brit. Chem. Abs.-B*, **54** [33] 726 (1935); see "Refractory—" *Ceram. Abs.*, **14** [7] 167 (1935).

Stability of hearth casing of Martin furnaces. A. Kulberg and G. Lyadvanskiĭ. *Domez*, No. 10, pp. 14–21 (1934); abstracted in *Referat. Silikatliteratur*, No. 1615 (1935).—The cause of the short life of hearth casings in many Russian Martin furnaces was studied. Most defects are caused by the carelessness of workmen when mixing the batch; with a mixture of dolomite and magnesite (2:1), the amount of Martin slag exceeded the 15% specified. In addition to the higher slag content, the grain size of the raw material was unsuitable. Examination showed a high FeO content, while microscopic analysis showed irregularity in the structure of the layers. The suitability of raw materials and working process was studied by a survey of the whole process of production of the casing. M.V.C.

BULLETINS

Fire tamers. Johns-Manville. Reviewed in *Mining*

Jour. [Phoenix], **19** [13] 34 (1935).—Research and development in the refractory cement industry are described. A brief description of the everyday uses of refractories is given. Illustrated. J.M.W.

Insulate with safety at any temperature. HARBISON-WALKER REFRACTORIES CO. Reviewed in *Mining Jour.* [Phoenix], **19** [13] 34 (1935).—The importance of the selection of proper refractories as well as the proper insulating materials for any industrial furnace is emphasized, and insulating and lightweight brick and their application are described. Three types of brick are described: *HW-777:* diatomaceous earth brick, weight 1.75 lb., safe working temperature up to 2000°F; the brick possesses high mechanical strength for this type of material and has more than six times the insulating value of high heat duty fire brick. *HW-111:* flint fireclay brick, weight 2.8 lb., safe working temperature up to 2500°F; the brick possesses high mechanical strength and its heating value is more than three times as great as that of high heat duty brick; its heat capacity is less than 30% as great. *HW-444:* silica brick, weight 2.8 lb., safe working temperature up to 2900°F; its insulating value is more than four times as great as that for usual silica brick and its thermal expansion is only about 70% as great. J.M.W.

Providing grog outlets with a protective coat. MERLIN. *Zitein-Tech. SO,* No. 683, 6 pp. (1936); abstracted in *Referat. Silikatliteratur,* **3** [12] 3552 (1936).—Grog drains are used for casting melted steel in steel mills. These are attacked by steel. Graphite drains proved to be unsatisfactory also as the steel is enriched by carbon from the graphite drains. M. recommends providing grog drains with a magnesite coat whose composition is discussed. The manufacture and application of magnesite protective coatings is briefly discussed. M.V.C.

PATENTS

Heat-insulating material. G. A. BOLE (Laclede-Christy Clay Products Co.). U. S. 2,073,138, March 9, 1937 (Aug. 9, 1930). A process of manufacturing heat-insulating material consists in molding a mass constituted of sized raw kyanite and a small amount of clay to which has been added sufficient chemical and dilute acid solution to produce bloating of the mass, drying the molded mass, and firing the dried mass at a sufficiently high temperature and at a rate to produce a highly cellular product.

Manufacture of refractory ware. SILIKA- UND SCHAMOTTE-FABRIKEN MARTIN & PAGENSTECHER AKT.-GES. Brit. 461,240, Feb. 24, 1937 (July 6, 1934).

Process of recovering alumina from aluminous siliceous material containing a substantial proportion of silica. H. G. C. FAIRWEATHER (Electric Smelting & Aluminum Co.). Brit. 461,117, Feb. 24, 1937 (June 20, 1936).

Terra Cotta

Constitution of ceramics. B. TAVASI. *Verre & Silicates Ind.,* **7** [33] 389–92; [34] 401–404 (1936).—The new building materials studied were gray antiacid porphyroid, gray antiacid lithoceramic ware, brown porphyroid for paving, and red lithoceramic ware for facing. They have a high mechanical resistance and compactness and are used like brick, from which they differ in their low porosity. They have nothing in common with clinker except the phenomenon of partial fusion. The firing temperature is 1100 to 1300°. The composition, characteristics (shown in photomicrographs), etc., are given. Researches showed that the essential constituents of porphyroid and gray lithoceramics are quartz glass, mullite, and accessory materials. These opaque ferriferous inclusions are essential in red lithoceramic ware and to a certain extent in brown porphyroid. Artificial sillimanite is not present. Porcelain contains the same constituents as porphyroid and gray lithoceramics, but the distribution is more uniform. Generally the quartz grains are bordered by fissures with rounded ends. M.V.C.

Flat tile. ANON. *Argile,* No. 162, pp. 17–19; No. 164, pp. 17–19; No. 165, pp. 15–19 (1936); No. 166, pp. 11–13 (Jan., 1937).—The manufacture of flat tile presents no serious difficulties. Soft, semifirm, or hard paste can be used and the clays need not be of the highest quality; providing they are not suceptible to frost, they need not have a high mechanical resistance. The operation of the drawplate and cutters used for the perfect shaping of flat tile is studied. A brief account of the manufacture of flat tile from hard paste in a friction press is given. The aging of tile for decorative purposes is accomplished (1) by mixing certain products, usually manganese, with the mass (this is the best, surest, and most lasting method although expensive), and (2) by coating with engobe or dry powder; the new sanding machine in which the powder is pressed into the paste insures better adherence. M.V.C.

Manufacture of salt-glazed stoneware pipes and fittings. A. COULHON. Translated in *Brit. Clayworker,* **45** [538] 330–31 (1937).—The burning of fuel in intermittent, semicontinuous, and continuous kilns is discussed. See *Ceram. Abs.,* **16** [4] 121 (1937). R.A.H.

PATENTS

Chimney pots. J. JOHNSON. Brit. 461,125, Feb. 24, 1937 (Sept. 2, 1936).

Combination flowerpot. R. H. LOCKYER. U. S. 2,072,172, March 2, 1937 (Dec. 16, 1935).

Flowerpot watering system. A. P. SCHEIN. U. S. 2,072,185, March 2, 1937 (Nov. 16, 1935).

Slip for the production of coatings on ceramic ware. SCHUTTE AKT.-GES. FÜR TONINDUSTRIE. Brit. 460,556, Feb. 10, 1937 (March 14, 1936).

Whiteware

Causes of defects and their cure. C. RANCKE. *Keram. Rundschau,* **44** [4] 37–38 (1936).—R. describes defects encountered in practice. Hairlines in glazes on crockery were due to exaggerated milling and incorrect weight of flint stones. Some porcelain was grayish because the lining of the mills was too soft. In one instance, the clay slurry intended for faience was treated too quickly; an irregular amount of quartz sand was introduced in the pieces,

causing cracks. Bubbles in lead glazes were caused by tight grates impeding the arrival of air. Excess of sulfur in coal gives yellow glazes; coal should be sprayed with limewater. Scaling of glazes may be caused by stagnant water; firing at high temperature is advocated. Poor colors are attributed to incorrect firing or inadequate substitution of boron oxide by borax. The iron plates of the grinder may introduce microscopic iron needles in the ceramic body. F.E.V.

Crazing and peeling of glazes. J. W. MELLOR. Translated in *Sprechsaal*, [27] 386–89; [28] 401–405; [29] 417–20; [30] 429–32; [31] 441–43; [32] 457–59; [33] 471–73; [34] 486–88; [35] 499–502; [36] 515–18; [37] 531–33; [38] 547–48 (1936); for abstract see *Ceram. Abs.*, **14** [9] 233 (1935). M.V.C.

Development of porcelain insulators. N. V. RAGHUNATH. *Electrotechnics*, **9**, 185–87 (1936). A.P.S.

Dolomitic faience: I. SHINICHIRO OGAWA. *Jour. Japan. Ceram. Assn.*, **44** [520] 246–53 (1936).—Experiments were made on the manufacture of dolomitic faience. (1) Raw materials: dolomite, Ōtoge white clay, and Honyama Kibushi-clay (a ball clay); the dolomite is produced at Tsukumi in Ōita Prefecture and contains only 0.08% of Fe_2O_3; Ōtoge clay contains 0.25% of TiO_2 and 0.10% of Fe_2O_3 and can not be used for white porcelain; Kibushi-clay has 0.58% of TiO_2 and 1.13% of Fe_2O_3. (2) Deformation eutectics: several eutectics at cones 7 to 8 and up in the binary and ternary systems. (3) Bodies: 8 bodies, consisting of Kibushi-clay 25%, Ōtoge clay 70 to 35%, and dolomite 5 to 40%. (4) Fire shrinkage: linear shrinkage at cones 03*a* to 3*a* ranges between 0.2 to 1.4%. (5) Moisture expansion: dolomite is effective in reducing the expansion. The expansion of the bodies containing 20% or less of dolomite is lowered by high firing, while that of the bodies containing 25 to 40% is raised. (6) Autoclave test of glazed ware: bodies containing 25 to 40% dolomite are sound; in biscuit firing, cone 03*a* is better than cone 3*a*. **II.** *Ibid.*, [521] 323–33.—As the preceding experiments indicated that dolomitic faience may be obtained with 25 to 40% dolomite, a further investigation was made of bodies composed of Kibushi-clay 20 to 25, Ōtoge clay 55 to 35, and dolomite 25 to 40% and fired to cones 03*a*, 1*a*, and 3*a*. Results are as follows: (*a*) Firing shrinkage varies only from 0.65 to 1.35%. (*b*) Transverse strength ranges from 175 to 230 kg./ sq. cm. (*c*) Moisture expansion is small and tends to increase on higher firing. (*d*) In the autoclave test all glazed specimens stand an 8 and 12 kg./ sq. cm. test, but some of those with a higher content of dolomite and fired to cone 1*a* or 3*a* craze on repeating the 12 kg. test. (*e*) Linear change of the raw materials and bodies on firing: the bodies expand up to 500 to 600°C, shrink slowly, followed by a marked shrinkage at 800 to 950°, and expand rapidly at temperatures between 950° and 1150°. The shrinkage and expansion cancel each other. This explains why the firing shrinkage is small. Chemical reactions and softening seem to begin at about 950° and 1150°, respectively, suitable biscuit temperatures being 1000° (cone 05*a*) to 1100° (cone 1*a*). (*f*) Thermal expansion of the biscuit ware: generally speaking, it is highly expansive. (*g*) Manufacture: the following body and glazes are now used at the Government Institute for Potteries in Kioto.

Body (cones 03*a* to 1*a*): Kibushi-clay 23, Ōtoge clay 47, and Tsukumi dolomite 30%.

Bright colorless glaze

$$\left.\begin{matrix}0.15\ K_2O\\0.20\ Na_2O\\0.30\ CaO\\0.35\ PbO\end{matrix}\right\}\ 0.25\ Al_2O_3\ \left\{\begin{matrix}2.5\ SiO_2\\0.5\ B_2O_3\end{matrix}\right.\ \left\{\begin{matrix}0.0002\ CoO\\0.0004\ Fe_2O_3\end{matrix}\right.$$

Frit for colorless glaze

$$\left.\begin{matrix}0.20\ Na_2O\\0.30\ CaO\\0.20\ PbO\end{matrix}\right\}\ \begin{matrix}1.7\ SiO_2\\0.5\ B_2O_3\end{matrix}\ \left\{\begin{matrix}0.0002\ CoO\\0.0004\ Fe_2O_3\end{matrix}\right.$$

Mat glaze — Frit for mat glaze

$$\left.\begin{matrix}0.05\ K_2O\\0.10\ MgO\\0.35\ ZnO\\0.50\ PbO\end{matrix}\right\}\ 0.05\ Al_2O_3\ 1.8\ SiO_2 \qquad PbO{\cdot}SiO_2$$

See "Researches—" *Ceram. Abs.*, **16** [2] 68 (1937). S.K.

Durability of ceramic frits, glazes, glasses, and enamels in service. J. W. MELLOR. Translated in *Sprechsaal*, **69** [42] 613–16; [43] 629–33; [44] 641–43; [45] 658–61; [46] 673–76; [47] 687–90; [48] 703–705; [49] 719–22 (1936); for abstract see *Ceram. Abs.*, **14** [9] 233 (1935). M.V.C.

Manufacture of pottery. A. D. *Argile*, No. 162, pp. 7–9; No. 164, p. 9 (1936); No. 166, p. 15 (Jan., 1937).—Culinary pottery can be classified as (1) pottery fired at a low temperature, 900 to 1050°, and (2) pottery fired at a high temperature (stoneware). A condensed account of their manufacture is given. M.V.C.

Methods of making vitreous fine ceramic bodies. F. LIPINSKI. *Keram. Rundschau*, **44** [1] 3–4 (1936).—Porcelain and stoneware have undergone little alteration for centuries. Artificial pressed ware is now a serious competitor of porcelain. Vitreous fine ceramic bodies are heterogeneous; they contain melted alumina-silicate crystals in a glass phase. L. describes new vitreous ceramic bodies containing up to 80% pulverized ferrochromium and silicon intended for the chemical industry. F.E.V.

Steatite in ceramics. ANON. *Argile*, No. 164, p. 25; No. 165, pp. 1–3 (1936); No. 166, pp. 3–5 (1937).—Steatite is used in special products for the electric industry, while talc, being less pure and grainy or flaky, is cheaper and more generally used. The theoretical formula of talc or steatite is $4SiO_2{\cdot}3MgO{\cdot}H_2O$ (31.7 MgO, 63.5 SiO_2, 4.75% H_2O); density 2.75 to 2.8; coefficient of dilatation 1×10^{-6}; fusing temperature 1500 to 1550°; resistance to crushing 150 to 250 kg./ sq. cm.; dielectric rigidity and insulating resistance are very high. Talc and steatite can not be used pure. Firing transforms steatite into steatite anhydride, $4SiO_2{\cdot}3MgO$, which has the new property of great hardness comparable to that of quartz (6 to 7). Steatite anhydride is composed of 95% eutectoid which explains the difficulty of obtaining a vitrified product, as it passes directly from the solid to the liquid state. A material which contains a high proportion of natural steatite has the following qualities: (1) higher resistance to acids than porcelain, (2) same resistance to abrasion as flint, (3) possibility of minimizing the surface of joints, and (4) homogeneous and regular wearing qualities. If feldspar and quartz are replaced by the eutectic talc-clay or kaolin in porcelain, a new vitrified medium, which

becomes impermeable to relatively low temperature, resists variations in temperature, and has good mechanical resistance, is obtained. In the U. S. S. R. steatite is used in place of magnesia for refractory brick for metallurgical furnaces. Steatite is used in the manufacture of (1) ceramic tile, (2) saggers, (3) electrical appliances, and (4) heat-resisting ceramic ware. M.V.C.

Talc porcelain: I-II. S. KONDO AND S. SUZUKI. *Jour. Soc. Chem. Ind. Japan*, **39** [12] 470–71B (1936).—Thermal expansion of bodies with high talc content was comparatively high. Transverse strength was highest with a feldspar content of 3 to 4%. Porcelain with a high talc content has less resistance to rapid change of temperature. M.V.C.

Thermal stresses in laboratory porcelain. STEPHAN SZTATECSNY. *Sprechsaal*, **69** [43] 627–29; [44] 639–41 (1936).—Equations were developed for stresses appearing on the cooling or chilling of glazed bodies and were applied to thin-walled porcelain pipes. Knowing the measurements, temperature fluctuations, and properties of the material (figure of thermal conductivity, strength, etc.), it is possible to determine exactly with the given equations how much the material will withstand (scaling or cracking of glaze, rupture of bodies). A literature index is given. M.V.C.

PATENTS

Ceramic composition and method of preparing. A. L. BENNETT (Malinite Corp.). U. S. 2,073,136, March 9, 1937 (April 14, 1934). A body adapted for use in plastic pressing and jiggering is characterized by an ability to exhibit plastic flow by the application of pressure thereto and coherence when caused to flow by such application of pressure, the body containing between 5 and 35% of clay, between 25 and 80% by weight of a material from the group consisting of pyrophyllite, tremolite, actinolite, sepiolite, and talc, and between 8 and 40% by weight of a matrix material high in alkalis from the group consisting of glass, sodalite, and colemanite, the body being acid to phenolphthalein and alkaline to methyl orange.

Ceramic tile composition. ANDREW MALINOVSZKY (Malinite Corp.). U. S. 2,072,460, March 2, 1937 (March 13, 1933). A ceramic composition consists of about 29 to 60% of magnesia-containing mineral from the group consisting of talc, steatite, tremolite, soapstone, and serpentine, 10 to 52% of ground common glass, and from 4 to 30% of clay, the composition being characterized by its ability to form a tough, fired product containing magnesia-containing material in a glassy matrix upon maintaining a body of the composition at a temperature of about 1600°F to about 2200°F for a period of time not exceeding 1 hr., the fired composition being adapted to receive and tenaciously retain a glaze.

Joining of ceramic insulating members and metallic members. PORZELLANFABRIK KAHLA AND H. HANDREK. Brit. 461,262, Feb. 24, 1937 (Aug. 13, 1934).

Shielded mica spark plug. HECTOR RABEZZANA (General Motors Corp.). U. S. 2,071,570, Feb. 23, 1937 (Feb. 14, 1935).

Tile construction. D. A. WALLACE. U. S. 2,073,130, March 9, 1937 (April 20, 1936).

Two-piece center wire spark plug. HECTOR RABEZZANA, T. G. MCDOUGAL, J. T. FORD, AND W. S. KIRK (General Motors Corp.). U. S. 2,071,571, Feb. 23, 1937 (Dec. 9, 1935).

Equipment and Apparatus

Applications of grid-controlled gaseous discharge devices. R. K. GESSFORD. *Instruments*, **10** [2] 45–47 (1937).—Grid glow tubes may be adapted to production-line control, oil-burner safety devices, as phototube amplifiers, in time-delay relays, for illumination dimming control, in manual or automatic motor speed control, spot welder control, and in many other applications. Theory and operation of tubes are discussed. R.W.R.

Brick press with two separate dies. REINHOLD STECHEMESSER. *Tonind.-Ztg.*, **60** [27] 353–55 (1936).—The operation of brick presses is discussed, and a new type of brick press with two separate dies is described. Illustrated. M.V.C.

Comparative gloss meter. SALFORD ELECTRICAL INSTRUMENTS, LTD. *Jour. Sci. Instruments*, **14** [1] 32–33 (1937).—The instrument is designed so that any flat surface on which it is placed is illuminated by a light beam incident at 45°. Light reflected at the same angle is collected and operates a photocell connected to an ammeter. Readings obtained are indicative of the relative gloss of similar surfaces. Lamp and meters are in two separate units. Illustrated. J.L.G.

Conveyer scale weighs filter cake. ANON. *Concrete* [Cement Mill Ed.], **45**, 107 (1937).—Weighing here is desirable as a check on the efficiency of the filtering equipment and as a regulation of both filter and kiln. A unique device gives an electric impulse for each unit weight passing on the belt. W.D.F.

De-airing. ANON. *Brit. Clayworker*, **45** [533] 182 (1936).—A de-airing machine is not a "cure-all" and it can not be substituted for means for securing proper preparation of the clay paste. The size of the apertures through which the clay paste passes must be regulated to suit the material and the vacuum desired. De-airing enables certain errors in designing and lubrication to be overlooked, but it does not eliminate them completely. When hollow ware is made, the bridge carrying the core should be further from the mouthpiece than is usually the case. Scraps of de-aired clay should be treated as fresh clay and not be directly returned to the machine. Variations in the vacuum are objectionable. The early stages of firing of de-aired clays require special attention because of the slow evolution of water. R.A.H.

De-airing clay in the tile industry. ALFRED TÄUBER. *Tonind.-Ztg.*, **60** [97] 1195–97 (1936).—The importance of strict supervision of the vacuum press to keep it working efficiently, to lengthen its life period, and to insure the improved quality of the ware is shown. M.V.C.

Diesel engine pyrometer. BROWN INSTRUMENT CO. *Instruments*, **10** [2] 33 (1937).—The new pyrometer com-

bines the indicator and selector switch in one case, eliminating the lead problem. A special temperature compensator is used. Several scales are available, and the pyrometer is calibrated within 1% of full range in the normal operating zone and within 2% outside of that zone. R.W.R.

Dynamics of drying. A. V. Jaroshevskiĭ. *Stroitel. Materialy*, No. 4, pp. 24–31 (1934). P.B. & E.S.

Electric flow meters. Bristol Co. *Instruments*, **10** [2] 37 (1937).—New electric flow meters for steam, liquids, and gases use the Metameter principle of telemetering. Readings are transmitted over a two-wire circuit, telephone circuits included, which does not enter into the calibration of the instrument. R.W.R.

Electrical precipitator removes finest particles. Anon. *Concrete* [Cement Mill Ed.], **45**, 119–20 (1937).—Electrical precipitation of dust removes all sizes, even those fine enough to enter the lungs of workers. The two types of electrical precipitators are horizontal flow and vertical flow. There are central electrodes of wire, and the other electrode is the grounded reinforcing steel in the wall. Dust collects on the wall until thick enough to fall off, when it falls into a hopper and is returned to the raw material stream. A velocity of 5 ft./sec. in the air stream will give about 95% precipitation of the dust. W.D.F.

Electrofilters make rapid advance in European industry. R. Heinrich. *Elektrotech. Z.*, **55** [17] 413–17 (1934); translated in *Concrete* [Cement Mill Ed.], **43** [2] 37–41 (1935).—H. describes the construction of electrical precipitators and devotes particular attention to the ionization and migration velocities of the dust as a function of the particle diameter, together with calculations of filter operation and uses in various industries, including cement. W.D.F.

Electron microscope. L. C. Martin, R. V. Whelpton, and D. H. Parnum. *Jour. Sci. Instruments*, **14** [1] 14–24 (1937).—A new two-stage electron microscope is described for producing magnified images of small objects by means of electron beams. The apparatus includes an optical microscope from whose field any required object detail can be brought to the electron system for electron magnification. Illustrated. J.L.G.

Equations and quadrant charts for determining the heat and air requirements for continuous driers. Hewitt Wilson and K. G. Skinner. *Jour. Amer. Ceram. Soc.*, **20** [4] 99–111 (1937).

Filter for photronic cells. Weston Electrical Instrument Corp. *Instruments*, **10** [2] 38 (1937).—A new glass correction filter (Viscor) has been developed which eliminates the effect of invisible radiation on the photronic photoelectric cell and adjusts the sensitiveness of this cell so that it is comparable with the eye. The total transmission of this filter is approximately 37.5%. R.W.R.

Furnace atmosphere quality recorder. Brown Instrument Co. *Instruments*, **10** [2] 34 (1937).—This equipment operates on the thermal conductivity principle, samples of gas mixture being continuously drawn from the furnace and passed through the thermal conductivity cells. If the gas is the result of complete combustion, the thermal conductivity of the gas will be less than 1; for incomplete combustion it will generally be greater than 1. A potentiometer recorder is used to record measurements, the chart being divided into two equal sections, one for complete and one for incomplete combustion. R.W.R.

Greater efficiency in grinding. Anon. *Concrete* [Cement Mill Ed.], **44** [12] 35–37 (1936).—Careful testing of the grinding in a compound mill may show that adjustments in the length of compartments will give greater efficiency. The shape and size of the grinding media are also important. Dividing a mill into longitudinal cells gives better balance of the load with more output and less power consumption. A new type of vertical grinder and drier is more efficient. W.D.F.

Hardness and hardness measurements: II, Theories and definitions of hardness. S. R. Williams. *Instruments*, **10** [2] 41–44 (1937).—Hardness is defined, the nature of matter is discussed, and physical properties allied to hardness are defined. For Part I see *Ceram. Abs.*, **16** [4] 123 (1937). R.W.R.

Immersion thermostat. Wilcolator Co. *Instruments*, **10** [2] 33 (1937).—A new high-capacity immersion thermostat consists of the thermostat unit and a brass well. The thermal element is a liquid-filled bulb and flexible-bellows type, which gives sensitive temperature control. A snap-action switch is used, with silver contacts. The thermostat can be operated in any position and is available in several types. R.W.R.

Kabus softness tester for ceramic materials. H. Hecht. *Keram. Rundschau*, **43** [7] 73–75 (1935).—K. has developed a practical apparatus to test the consistency of plastic materials. The penetration of a cylinder, under given conditions, is read directly in percentage on a dial. Results are reproducible. It is now possible to regulate water addition to obtain maximum workability. Conversely, the tester determines the quantity of water added in a known material. Illustrated. See "Control—" *Ceram. Abs.*, **14** [7] 169 (1935). F.E.V.

Larger size crusher. Alloy Steel and Metals Co. *Mining Jour.* [Phoenix], **19** [17] 31 (1936).—A new 10- x 20-inch unit has been developed by the manufacturers. The crusher is of all-steel construction with forged steel shaft and bronze bearings and uses forced feed for larger capacity. J.M.W.

Measuring settling rates of mineral suspensions with data on the flotation of quartz. A. W. Fahrenwald and Joseph Newton. *Eng. Mining Jour.*, **138** [1] 22–28 (1937).—The three methods of measuring the settling rate used in this investigation were (1) siphon method, (2) displacement method, and (3) photoelectric method. (1) In the siphon method, a known weight of material is suspended in a known volume of liquid and allowed to settle for a certain time; the suspended material is siphoned off. The settled material in the bottom of the container is filtered, dried, and weighed. The difference between this and the weight used is the amount remaining suspended. (2) In the displacement method, a special hydrometer is placed in a graduated beaker filled with the mineral-water suspension to be tested. The time required for the hydrometer to settle a prescribed distance is determined with a stop-watch. (3) The photoelectric method employs the fact that as the suspension settles the opacity of the liquid above the settled material decreases. The amount of light transmitted after a given time through a given

column of suspension is a measure of the amount of solid still in suspension. Different reagents were added to the quartz suspensions, and p_H measurements were made after settling curves had been determined. The authors conclude that quartz is fully dispersed in distilled water, the particles having a negative charge. The anchored ion is SiO_3^{--} or $HSiO_3^-$, and the outer free-swimming ion, H^+. An aqueous quartz suspension is precipitated by sodium hydroxide. The salts of sodium in which the anion is the radical of a weak acid are precipitants of quartz only when the acid of the salt is less ionized than silicic acid. Calcium cation, Ca^{++}, is a strong precipitant of quartz only in the presence of hydroxyls. With solute cations, if the hydrate of the solute cation is less soluble than silicic acid, the suspension is little affected. If the hydrate of the solute cation is slightly soluble and the silicate of the cation insoluble, precipitation occurs. Sodium salts are not promoters of quartz flotation. Calcium and barium hydroxides are precipitants of quartz in aqueous suspension and are also promoters of quartz flotation. Base metal nitrates were found to have widely different quartz activating properties. The p_H of the suspension is an important factor in flotation. 13 figures, 4 tables. J.L.G.

Metallurgical progress in clayworking. ANON. *Brit. Clayworker*, **45** [538] 342–43 (1937).—Improvements in heat-resisting steels, steel castings, alloys for brick dies, stainless steels, spring steels, and electric welding, as applied to the ceramic industry, are discussed. A liquid rubber for protecting steel surfaces is commented upon. R.A.H.

Multipointer gage. BAILEY METER CO. *Instruments*, **10** [2] 32 (1937).—In this new diaphragm-type multipointer gage, developed for boiler-room service, the diaphragm material is resistant to oil, acid, caustic, and heat and is said to possess exceptional flexibility. Operating details of the gage are given. This gage is available in casings with 1 to 12 units, surface, semiflush, or flush mounted. R.W.R.

Null-method flow measuring and integrating equipment. LEEDS & NORTHRUP CO. *Instruments*, **10** [2] 35 (1937).—This device can be used with orifice meters or any other differential producer which gives a square-root relation of flow to differential. Measurement of differential is not accomplished by deflection, but by opposition of a mechanical force automatically varied to restore balance whenever the value of differential changes. This force is exerted by a fly-ball system driven by an electric motor and is proportional to the square of the motor speed, so that the motor speed is proportional to flow rate and can be indicated on a tachometer. R.W.R.

Photoelectric relays. GENERAL ELECTRIC CO. *Instruments*, **10** [2] 40 (1937).—No amplifier tube is used, but a Thyratron tube is used to control a magnetic contactor capable of making or breaking 35 amp. a.c. or carrying 10 amp. continuously. A light flash or interruption of $^1/_{30}$ sec. is sufficient to cause operation, or an illumination of a 1-ft. candle. Another type of relay requires only a $^1/_{10}$-ft. candle for operation. These relays may be used for slow light changes, with snap action of the contactor due to the Thyratron action. R.W.R.

Portable self-contained immersion pyrometer. TAMMS SILICA CO. *Instruments*, **10** [2] 39 (1937).—A new pyrometer for measuring temperatures of molten brass or aluminum is provided with separable direct immersion base couples for each metal. These are easily fastened to the handle which holds the indicator. R.W.R.

Position-type motor for telemetering, etc. GENERAL ELECTRIC CO. *Instruments*, **10** [2] 33 (1937).—A new Selsyn-type motor for use on telemetric gages, etc., is described. R.W.R.

Separation into component parts of dry mixes. ANON. *Keram. Rundschau*, **44** [4] 38–40 (1936).—When a silo is filled with dry mixes for storing and then emptied through an aperture at its bottom, the dry mix separates into coarse and fine particles, which is the cause of various defects in the finished ware. The installation of a pyramid-like distributor over the aperture through which the mix is removed will prevent this separation. Illustrated. M.V.C.

Thermostatic trimetal. LAMINATED METALS CORP. *Instruments*, **10** [2] 32 (1937).—Tri-ply Metal has been developed for thermostatic applications requiring smooth and uniform motion of the free end of the element, within extremes of 0° and 1200°F in damp or saturated atmospheres or in water. It consists of three layers, the two outer ones of equal thickness and the inner one relatively thin. One external layer (active) is a 22% nickel steel, the other external layer a copper alloy (highly active), and the internal layer 36 to 42% nickel steel (inactive). These three layers are combined by a new method which prevents separation. R.W.R.

"Vibrect" sieves and screens (sieve vibrating horizontally). PIERRE RENAULT. *Rev. Matériaux Construction Trav. Publics*, No. 327, pp. 183–85B (1936).—The "Vibrect" sieves (Soc. anon. Établissement G. Pinette) are horizontal sieves for dry and wet materials. Their construction and operation are given in detail. The Vibrect is a great improvement over older systems. It has easy access to all parts, and the vibration is completely isolated from the circuit of the material and separated from the cloth. As the sieve functions horizontally there is no loss because of height; the sieve also acts as a conveyer. See *Ceram. Abs.*, **16** [1] 33 (1937). M.V.C.

X-ray and welding, the foundryman's aid to quality steel castings. C. M. UNDERWOOD AND E. J. ASH. *Trans. Amer. Foundrymen's Assn.*, **7** [3] 481–510 (1936).—A review is given of the assistance that X-ray studies and welding of steel castings have rendered to the Naval Gun Factory. H.E.S.

BULLETIN

Crushing, grinding, and pulverizing equipment for the refractories industry. A. F. GREAVES-WALKER. *Amer. Refrac. Inst. Tech. Bull.*, No. 64, 12 pp. (Jan., 1937).—Proper selection of crushers and pulverizers requires careful study and often experimentation, especially in the case of the softer fire clays which are often difficult to reduce to the desired particle sizes. The equipment used to reduce raw materials accomplishes the reduction either by crushing, grinding, impact, or a combination of two or three of these actions. The following list classifies crushing and pulverizing equipment according to the principle involved in its operation: (1) crushing machines: jaw crushers

(Blake and Dodge type), gyratory, or eccentric crushers; (2) crushing and grinding machines: smooth-roll and single-roll crushers (stationary plate, swinging plate), Kent and Raymond mills; (3) crushing, grinding, and impact machines: dry pan, grinder, disintegrator; (4) impact machines: hammer mill, ring, and squirrel-cage pulverizers, rock and shale crusher; (5) impact and grinding machines: ball, tube, rod, and Hardinge mills; (6) plastic and wet grinding machines: wet pan, Lancaster mixer, ball, and tube mills. A description and the advantages and uses of the above equipment are presented. H.E.S.

PATENTS

Apparatus for cleaning articles of ceramic materials. H. V. Schweitzer. U. S. 2,073,184, March 9, 1937 (Nov. 11, 1935). An extrusion press mouthpiece for producing hollow bodies from plastic material comprises means for producing a hollow strand of plastic material, means for producing plugs, a hollow core for inserting the plugs at predetermined intervals into the hollow strand, and means for introducing a fluid medium to the periphery of the outlet end of the core to assist in severing the individual plugs from the mass of plastic material in the hollow core.

Apparatus for de-airing clay, etc. J. M. Willis and C. L. Willis. Brit. 460,785, Feb. 17, 1937 (Aug. 31, 1935).

Apparatus for producing hollow brick closed on all sides. Jan Putterlik. U. S. 2,074,063, March 16, 1937 (June 12, 1934). Apparatus comprises the combination of a traveling conveyer, lower impacting means disposed at the sides of the conveyer and directed above and across it to a zone of action sufficiently above the conveyer, so that the impacting means may effectively cover the lower surface of an object disposed in the zone, upper impacting means directed downwardly toward the zone for covering the upper surface of an object disposed therein, and means carried by the conveyer for supporting an object in the zone.

Means for removing tile from pallets. G. H. Carter. Brit. 461,293, Feb. 24, 1937 (Oct. 5, 1935).

Method for producing tile. W. G. Johnson and R. C. Zappe (Pomona Tile Manufacturing Co.). U. S. 2,073,615, March 16, 1937 (June 17, 1935). The method of forming a roughened cement bonding suface on the interior of a ceramic article molded from a dust body is described.

Vibratory apparatus. H. E. Wurzbach and C. H. Konold. U. S 2,071,373, Feb. 23, 1937 (Jan. 12, 1935).

Kilns, Furnaces, Fuels, and Combustion

Automatic temperature control of electric furnaces. L. Beuken. *Elektrowärme*, **6** [12] 333–35 (1936).—Principles and factors involved in the control of temperature within the narrow limits of ±1°C and less are discussed, and methods are explained with examples of metallurgical and ceramic charges. Attention is called to the importance of making measurements at the correct places in the furnace. M.H.

Building and operating ceramic gas furnaces. R. *Tonind.-Ztg.*, **60** [101] 1245–47 (1936).—Gas-fired annular kilns with uniform fire, chamber annular kilns, and gas chamber kilns with adjustable fire are distinguished by their comparatively low fuel consumption and safety of operation. The tunnel kiln has a stationary flame and is well adapted to gas firing. Gas firing is easily regulated, fires well, and gives a good color. There is no coal dust or ash, and kiln masonry lasts longer. These benefits outweigh the higher cost of operation. M.V.C.

Chemical engineering in the gas industry. T. Campbell Finlayson. Read before Chem. Eng. Congress, World Power Conference, London, June, 1936; abstracted in *Gas World*, **104** [2708] 639 (1936). F.G.H.

Chemical nature of coke. H. L. Riley. *Gas World* [Coking Section], **23** [281] 17–22 (1936). F.G.H.

Combustion levels. W. T. David. *Nature*, **139** [3506] 67–68 (1937).—D. explains the discrepancy between the temperatures and pressures observed in gaseous explosions, which do not reach the calculated values, by assuming that the effective pressure is the instantaneous pressure in the flame front. From two photographs of flame travel by Bone and Frazer, he infers that the flame temperature increases as the pressure in the flame front increases. He defines "combustion level" as the ratio of the energy which can be accounted for in flame gases (on the assumption that they are normal gases) to the heat of combustion of the inflammable gaseous mixture. J.L.G.

Furnace atmospheres and their effects. John W. Cobb. *Gas World* [Ind. Gas Supp.], **8** [8] 14–16 (1936).—The effect of various furnace atmospheres upon the quality of glazes and enamels is briefly discussed. F.G.H.

Gas for industrial heating. John MacIsaac. *Gas World* [Ind. Gas Supp.], **8** [9] 9–13 (1936).—The application of gas firing in pottery kilns, optical glassmelting furnaces, and glass enameling furnaces is briefly described. F.G.H.

Gas and the potteries. Alexander MacKay. *Gas World* [Ind. Gas Supp.], **8** [10] 16–18 (1936).—The use of manufactured gas in the firing of several varieties of whiteware and in many other minor phases of whiteware production is discussed. Illustrated. F.G.H.

Heat balance and performance of a muffle tunnel kiln fired by town gas. E. Rowden. *Bull. Brit. Refrac. Research Assn.*, No. 41; *Refrac. Materials Joint Comm., Inst. Gas Engrs., 27th Rept.*, pp. 70–84 (1936). R.F.R.

Heating-up time and heating-up energy consumption of electrical furnaces. K. Mertens. *Elektrowärme*, **6** [12] 338–42 (1936).—An example illustrates how, by correctly dimensioning the furnace, the stored heat and the idling losses can be reduced considerably so that the heat economy of the furnace is improved. M.H.

Low-temperature carbonization of coal. F. Müller. Read before Chem. Eng. Congress, World Power Conference, London, June, 1936; abstracted in *Gas World*, **104** [2708] 639 (1936). F.G.H.

Measuring the specific "charge of fire box" in oil firing. E. Graf. *Feuerungstechnik*, **23** [4] 37–40 (1935).—G. describes experiments on measuring the charging of fire

boxes, hearths, and firing chambers; the efficiency of the latter; determination of the degree of efficiency and the best combustion conditions; measurements of the fineness of pulverization; mean size of drops; viscosity; and relationship between the charging of the fire chamber and the size of drop. Illustrated. M.V.C.

Small gas governors. H. J. Hadow and L. H. Pinkess. *Gas World*, **105** [2728] 452–62 (1936).—Factors influencing the design and performance of small gas governors are discussed in detail. Illustrated. F.G.H.

Weighing and sampling of coal. P. B. Ridout and S. Brooks. *Gas World* [Coking Section], **23** [282] 11–13 (1936).—Methods and types of equipment are described in detail. Illustrated. F.G.H.

BULLETIN

Dust-prevention treatment of solid fuels. L. D. Schmidt. *U.S. Bur. Mines Information Circ.*, No. 6932, 10 pp. Free. S. presents information in answer to inquiries received by the Bureau as to dust-prevention treatment of coal and coke. The material is based entirely upon publications by others and on communications to the author. R.A.H.

PATENTS

Process and apparatus for firing porcelain or ceramic material in electrically or indirectly heated tunnel furnaces. Keramische Industrie-Bedarfs-Akt.-Ges. Brit. 460,386, Feb. 10, 1937 (Dec. 22, 1934).

Tunnel kilns. Gibbons Bros., Ltd., and W. E. Gibbons. Brit. 461,088, Feb. 24, 1937 (Sept. 11, 1935).

Geology

Adamite from Chloride Cliff, California. Joseph Murdock. *Amer. Mineralogist*, **21** [12] 811–13 (1936). F.J.Z.

Argillaceous schists of Donbass. A. I. Iedvabnik and L. I. Michoulovitch. *Mineral. Syr'e*, **11** [3] 38–42 (1936); abstracted in *Chimie & Industrie*, **36** [6] 1143 (1936).—The argillaceous schists of Donbass are of two types: nonrefractory and refractory (P.C.E. 28–29 to 35). Because of low plasticity they are used only as thinning material (grog). The mechanical resistance of schist grog is sufficient, but porosity increases above cone 14. Brick from this grog are suitable for masonry in blast furnaces. The nonrefractory schists are used for building material and must be made by the dry-press method because of the insufficient plasticity of the schist. M.V.C.

Bauxite deposits in Austria and their practical use. L. Waagen. *Z. Prakt. Geol.*, **44**, 133–43 (1936); abstracted in *Chem. Zentr.*, **1936, ii**, 4245.—Austria has two large bauxite deposits, one near Salzburg, and the second at Weissbach-St. Gallen; Jugoslavia also has large bauxite deposits. M.V.C.

Bentonite. Victor Charrin. *Argile*, No. 166, pp. 7–9 (Jan., 1937).—Different colloidal clays are often incorrectly called bentonites because they have some of the properties of bentonites. Any clay which does not swell at least 5 or 6 times its volume when in contact with water is not a bentonite. The properties of bentonite, swelling, absorption, colloidal properties, and dispersion, are discussed. M.V.C.

Deposits of refractory clay of Ekaterinovka. K. G. Gloukhenki. *Mineral. Syr'e*, **11** [3] 36–38 (1936); abstracted in *Chimie & Industrie*, **36** [5] 929 (1936).—Clays of Ekaterinovka, especially the red clays, show a high alumina content. In the red clays alumina amounts to 36.64%; in the gray clays it varies between 30 and 40%. Average depth of the deposits is 18 m. M.V.C.

Diatomaceous earth: I. F. A. Harrison. *Mining Mag.*, **56**, 9–17 (1937).—The many uses for diatomaceous earth are described. **II.** *Ibid.*, pp. 88–92.—Compacted diatomaceous earth is mined by splitting along the stratifications. It is then prepared, calcined, milled, and sized with cyclones. The finest material is caught by a filter and is used as fine abrasive. The equipment should be dust-tight because of the silicosis hazard. Dust respirators are ineffective because of the absorption of moisture by the diatomite. W.D.F.

Industrial minerals. Anon. *Clay Prod. News*, **9** [11] 3 (1936).—The production of quartz and silica sand in Canada during 1935 amounted approximately to 230 M tons; 2641 M silica brick were produced. This entire production was consumed in Canada. M.C.S.

Kaolins of U. S. S. R. A. J. Voitsekhovskiĭ. *Gornyĭ Zhur.*, **112** [10] 53–61 (1936); abstracted in *Chem. Zentr.*, **1937, i**, 813.—Deposits, mining, working, and use of Russian kaolin are discussed in detail. M.V.C.

Magnesite deposits at the Amberger Hütte. A. Unterladstätter. *Berg- & Hüttenmänn. Jahrbuch*, **84** [4] 148–49 (1936).—Stratigraphic conditions and the composition of the deposits are described briefly. M.H.

New property of matter: reversible photosensitivity in hackmanite from Bancroft, Ontario. O. Ivan Lee. *Amer. Mineralogist*, **21** [12] 764–76 (1936).—Hackmanite, from a point near Bancroft, Ont., undergoes a remarkable color intensification following a brief exposure to a suitable source of ultra-violet light, including the argon bulb, iron spark, carbon arc with cored carbons, and quartz-tube mercury-vapor lamp, changing from colorless or pale pink to a raspberry shade or deep violet. With the argon bulb, however, a much longer exposure is required. By means of selective filters, the exciting radiation has been determined as being not longer than about 4800 Å, and extending down to about 2250 Å and perhaps lower. The induced color slowly fades in darkness to a light red-violet, but fades rapidly and nearly completely on exposure to strong light, the radiation responsible for the reversal phenomenon having a peak in the visible region in wave-lengths shorter than yellow, although extending to 7500 Å. Longer wave-lengths up to 39,000 Å have no effect. The intensification and reversal may be repeated indefinitely and is suspected of being connected with a known presence of a trace of manganese, spectographic analysis disclosing 0.001% of the element. The presence, however, of the extraneous elements Li, Ga, Pb, and Nd was also revealed, as well as traces of Be, Ba, Sr, and perhaps P, some of which may also be involved either in its photosensitivity or luminescent properties or both. The pink sodalite, thus exhibiting color intensification and reversal, fluoresces a salmon color when viewed with the aid of a Corning

red-purple Corex A No. 986 filter and phosphoresces sky blue; colorless, undetermined associated minerals may phosphoresce bluish, yellowish, greenish, orange, or not at all. It is suggested that both the partial recovery of color in darkness following reversal and the partial reversal in darkness following excitation are due to concomitant phosphoresence having compound radiations. Some reversibly photosensitive and thermosensitive substances of related interest are discussed. F.J.Z.

Occurrence of refractory clays. W. PETRASCHECK. *Berg- & Hüttenmänn. Jahrbuch*, **84** [4] 145–48 (1936).—The nature of stratification in which refractory clays can be found, their origin and composition, and deposits in Europe and America are discussed. In general, they are translocated kaolins and can be found in old massives and epeirogenic spaces, but orogenic sedimentations do not contain highly refractory clays. M.H.

Oriented inclusions of tourmaline in muscovite. CLIFFORD FRONDEL. *Amer. Mineralogist*, **21** [12] 777–99 (1936).—F. presents a study of the habit, plane of flattening, and orientation to the mica of tourmaline crystals inclosed between the basal cleavages of muscovite. The study is largely statistical and includes an analysis of 710 examples from Gilsum, N. H., and 109 examples from New York, N. Y. F.J.Z.

Purification of kaolin: data on the classification of quartz and muscovite. HEWITT WILSON AND G. J. MIDDLETON. *Jour. Amer. Ceram. Soc.*, **20** [4] 126–35 (1937).

Surface behavior of zeolites. V. R. DAMERELL AND R. CADLE. *Jour. Phys. Chem.*, **39** [5] 693–94 (1935).—The surface behavior of zeolites during dehydration is studied. The water content of samples of scolecite and analcite of two different average particle sizes was first determined. Using an equation developed earlier, the percentage of water when no adsorption had taken place was then calculated. Comparison of the data leads to the conclusion that water variation of the scolecite was due to a change in surface-adsorbed water, whereas water content within the lattice does not change. At low vapor pressures water is lost from the surface portions of the analcite lattice, forming a zone of skeleton lattice at the surface of the particles. C.J.P.

X-ray study of pucherite. W. F. DELONG AND J. J. DELANGE. *Amer. Mineralogist*, **21** [12] 809 (1936). F.J.Z.

BOOKS AND BULLETIN

Geology and mineral resources of the Butler and Zelienople quadrangles, Pennsylvania. G. B. RICHARDSON. *U.S. Geol. Survey Bull.*, No. 873. Supt. of Documents, Govt. Printing Office, Washington, D.C. Price 45¢. This report is one of a series of publications on the geology and mineral resources of the Appalachian plateaus. The Butler and Zelienople quadrangles together include about 450 sq. miles in Butler, Beaver, and Lawrence counties, western Pa. Limestone, sandstone, and shale are present. There are extensive deposits of clay, and iron ore has been mined. R.A.HEINDL

Mineralogy (Mineralogie). R. BRAUNS. (Sammlung Göschen, Vol. 29.) Walter de Gruyter & Co., Berlin, 1936. 7th revised ed. 146 pp. Price 1.62 gold marks. Noted in *Nature*, **139** [3508] 133 (1937).—B. describes 120 minerals. Optical properties except dichroism are not mentioned. J.L.G.

Mineralogy: Introduction to the Study of Minerals and Crystals. E. H. KRAUS, W. F. HUNT, AND L. S. RAMSDELL. McGraw-Hill Book Co., Inc., New York, 1936. 3d ed. ix + 638 pp. Reviewed in *Nature*, **139** [3508] 133 (1937).—Sixty illustrations and new material on physical properties, the polarizing microscope, crystal structure and X-ray analysis, and the formation and occurrence of minerals have been added to this edition. J.L.G.

Chemistry and Physics

Adsorption on measured surfaces of vitreous silica. W. G. PALMER AND R. E. D. CLARK. *Proc. Roy. Soc.* [London], **A149**, 360–84 (1935).—For theoretical treatment of the phenomena of adsorption, vitreous silica was chosen because of its nearly ideal properties. The absolute surface available for adsorption was determined from measurements of the initial rate of solution in dilute hydrofluoric acid by conduction measurements with a specially constructed cell. The adsorption of organic vapors at 25° was measured on carefully purified surfaces and plotted in micromols per square meter against $p/p_{satn.}$ The surface areas covered by molecules were calculated and found to agree with other values. They pointed to films containing two complete unimolecular layers. Langmuir's formula was shown to be applicable only to the restricted parts of the isothermals at pressures where the unsaturated film consists of unimolecular "islands" of liquid. A more general expression is proposed to connect adsorption potential with amount adsorbed, $d\epsilon/dx = k\epsilon$. A. P.

Determination of barium sulfate and free and combined silica in iron ores. E. CHAUVENET, P. AVRARD, AND J. BOULANGER. *Congr. Internat. Quim. Pura Aplicada, 9th Congress, Madrid, 1934*, **6**, 222–24; abstracted in *Chem. Zentr.*, **1937**, **i**, 939. M.V.C.

Determination of grain size of a fine crystalline powder. M. YAMADA, Y. ABE, AND I. TESIMA. *Science Repts. Tôhoku Imp. Univ., Series 1, Honda Anniversary Vol.*, pp. 67–71 (Oct., 1936).—The influence of the lattice distortion in crystal grains upon the breadth of the Debye-Hull lines is discussed. W.D.F.

Determination of quartz in presence of silicates. WILLARD R. LINE AND PAUL W. ARADINE. *Ind. Eng. Chem., Anal. Ed.*, **9** [2] 60–63 (1937).—A new method in which silicates are decomposed by fluoboric acid is proposed for the determination of free silica in the presence of silicates. This acid has less action on quartz than fluosilicic acid and is more stable at elevated temperatures. The decomposition of a number of common insoluble silicates has been determined, and the analyses of several synthetic silicate-quartz mixtures are reported. These results show that the amount of quartz in the synthetic mixtures can be determined with a precision of approximately 1%. F.G.H.

Determination of sulfur occurring as sulfide in Portland

cement. HARRY A. BRIGHT. *Jour. Research Nat. Bur. Standards*, **18** [2] 137–39 (1937); R.P. 968. Price 5¢.—A modification of the usual evolution method for the determination of sulfur is described wherein stannous chloride is used during solution of the sample to prevent the oxidation of hydrogen sulfide by the higher oxides of manganese and iron. R.A.H.

Effect of temperature and frequency on the anomalous variation of high-frequency resistance in quartz. K. NAKAMURA. *Science Repts. Tôhoku Imp. Univ., Series 1*, **25**, 590–97 (1936).—The high-frequency resistance of a quartz plate cut perpendicular to its optic axis was measured from room temperature to 700°C and at 350, 1000, and 2000 kc. The resistance passes through a minimum as the temperature increases, and this minimum value becomes less and occurs at lower temperatures as the frequency increases. W.D.F.

Equilibrium diagram of system $CaO{\cdot}TiO_2{\cdot}SiO_2$–MnO–$TiO_2$. K. IWASÉ AND U. NISIOKA. *Science Repts. Tôhoku Imp. Univ., Series 1*, **25**, 504–509 (1936).—The system was determined by microscopic examination of quenched specimens under reflected light, by thermal analysis, and by X-ray analysis. This is a simple eutectic system, the eutectic being at 49% $MnO{\cdot}TiO_2$ and 1210°C. The $CaO{\cdot}TiO_2{\cdot}SiO_2$ takes 18% $MnO{\cdot}TiO_2$ into solid solution at the eutectic point. W.D.F.

Equilibrium diagram of ternary system $CaO{\cdot}Al_2O_3{\cdot}2SiO_2$–$CaO{\cdot}TiO_2{\cdot}SiO_2$–$CaO{\cdot}SiO_2$. K. IWASÉ AND U. NISIOKA. *Science Repts. Tôhoku Imp. Univ., Series 1, Honda Anniversary Vol.*, pp. 444–53 (Oct., 1936).—The equilibrium diagram was determined by the microscopic examination of quenched specimens with reflected light. There is only one nonvariant point, the ternary eutectic, at titanite 25, anorthite 37.5, and wollastonite 37.5%, at 1240°C. The system $CaO{\cdot}SiO_2$–$CaO{\cdot}Al_2O_3{\cdot}2SiO_2$ was redetermined. It is the simple eutectic type, with the eutectic at wollastonite 57% at 1283°C. W.D.F.

Experiments in quantitative mineralogical dust analysis. J. H. HELLMERS AND H. UDUFT. *Zeiss Nachr.*, **2** [1] 1–9 (1936).—For the purpose of dust analysis the ordinary chemical analysis is not always suitable. It is necessary to understand the chemical and mineralogical composition of the dust. The following procedure is recommended. A qualitative examination is made with the polarizing microscope. Then it is decided which of the minerals found are to be individually determined and which are to be combined. The refractive indices of these minerals are compared, and the dust sample is introduced into a Zeiss konimeter with attached dust chamber and a ten-field object plate. The first dust spot is photographed under a microscope provided with a polarizing attachment. An embedding fluid is selected, preferably that with the lowest refractive index, and the spot is again photographed. Then the nicol is crossed and a third photograph is taken; after turning the object stage 45°, a fourth photograph is taken. Enlargements and comparisons are made. Illustrated. L.E.T.

Formation reactions and phase equilibria in clinkers containing magnesia. H. ZUR STRASSEN. *Zement*, **25** [14] 218–21 (1936).—The behavior of lime and magnesia in the presence of the acidic clinker components is different. The analysis of ternary systems containing three of the components, CaO, MgO, Al_2O_3, Fe_2O_3, SiO_2, shows that magnesia may be bound to the acidic oxides only if there is not sufficient lime to saturate excess alumina to $CaO{\cdot}Al_2O_3$ or excess iron oxide to $2CaO{\cdot}Fe_2O_3$, previous formation of $2CaO{\cdot}SiO_2$ and $4CaO{\cdot}Al_2O_3{\cdot}Fe_2O_3$ being taken for granted. The behavior at 1250°C of $2MgO{\cdot}SiO_2$ (forsterite) and $2CaO{\cdot}MgO{\cdot}2SiO_2$ (akermanite) in the presence of $CaCO_3$ was investigated by X-ray methods. The displacement of MgO by CaO is quick and complete, although the formation of intermediary products (monticellite, merwinite) is certain. The reactions, $2CaO + 2MgO + SiO_2 = \beta\text{-}2CaO{\cdot}SiO_2 + 2MgO$ and $4CaO + 2MgO + Al_2O_3 + Fe_2O_3 = 4CaO{\cdot}Al_2O_3{\cdot}Fe_2O_3 + 2MgO$, are realized in the solid state at 1000°C. There is a transient formation of a limited percentage of merwinite ($3CaO{\cdot}MgO{\cdot}2SiO_2$) and spinel ($MgO{\cdot}(Al, Fe)_2O_3$). If minerals of high lime content are present in Portland clinker, no magnesia compound is in equilibrium. If such a compound is added (slag), it is quickly decomposed and equilibrium is reached under normal firing conditions. F.E.V.

Fusion relations of iron-orthoclase. GEORGE T. FAUST. *Amer. Mineralogist*, **21** [12] 735–63 (1936).—An examination of the equilibrium relations existing along the section $K_2O{\cdot}6SiO_2$–Fe_2O_3 of the ternary system K_2O–SiO_2–Fe_2O_3 has shown that the compounds iron-orthoclase ($KFeSi_3O_8$) and iron-leucite ($KFeSi_2O_6$) exist and that they can be prepared from dry melts. On heating, the iron-orthoclase dissociates into iron-leucite and a liquid, and the iron-leucite in turn dissociates into hematite and a liquid. Hematite is the stable-phase at the liquidus 1265°C. The difficulty in the synthesis of iron-orthoclase can be traced, in part, to these complex incongruent melting relations. Powder X-ray diffraction patterns indicate the similarity of the two potash-iron silicates with the corresponding aluminum compounds. The question of the ferric feldspars and the entry of the iron-orthoclase molecule into the feldspars proper has been critically received. F.J.Z.

Hydrolysis of sodium aluminate. A. MAFFEI. *Gass. Chim. Ital.*, **64**, 149–60 (1934).—A formula is derived which determines, by means of the measurement of the electrical conductivity as a function of the concentration, the hydrolysis constant of the salt. M.H.

Influence of phosphoric acid on clays. P. P. BUDNIKOV, M. I. NEKRICH, AND A. B. KVITNITZKIĬ. *Zhur. Priklad. Khim.*, **9** [6] 986–93 (1936).—The influence of phosphoric acid on erosion was investigated on fire clay and washed kaolin, unfired, or fired at 200°, 500°, 600°, 700°, and 800°C; 2.5% phosphoric acid was added to the clay and 2% to the kaolin in all cases. Air-dry samples were held for 2 hr. at 120° in a drying chamber. They were then introduced on a network in a glass containing distilled water or an acid solution. The cause of a decrease in the eroding properties of clay and kaolin effected by phosphoric acid is seen in the processes of coagulation and aggregation of colloids that take place between their components. This was evidenced by a higher thermal effect determined in the diphenylmethane calorimeter. The colloidal character of unfired clay and kaolin facilitates the interaction. In fired materials it is to be ascribed to a higher activity of the components of the kaolin nucleus at 700° to 800°; simultaneously, there is possible the formation of aluminium phosphates and of silica phos-

phates. It is concluded that the interaction of acid with clay and kaolin leads to the formation of a complex more stable to the influence of water and acids than clay. A preliminary treating of clay samples by hot water (about 80°) increases their stability toward phosphoric, sulfuric, and hydrochloric acids. The process of interaction of clay with phosphoric acid is connected with a considerable thermal effect. P.B. & E.S.

Metastable crystallization of $CaTiO_3$, TiO_2, SiO_2 in place of $CaO{\cdot}SiO_2{\cdot}TiO_2$ due to supercooling of the latter. K. Iwasé and M. Fukusima. *Science Repts. Tôhoku Imp. Univ., Series 1, Honda Anniversary Vol.*, pp. 454–64 (Oct., 1936).—By means of thermal analysis and microexamination of quenched specimens, the stable equilibrium diagrams of the two systems $CaO{\cdot}TiO_2$–SiO_2 and $CaO{\cdot}SiO_2$–TiO_2 have been determined. In both systems the compound, $CaO{\cdot}TiO_2{\cdot}SiO_2$, occurs, forming simple eutectics with all components. By supercooling the melt, metastable crystals of SiO_2, TiO_2, and $CaO{\cdot}TiO_2$ occur in the CaO–TiO_2–SiO_2 system, and $CaO{\cdot}SiO_2$, $CaO{\cdot}TiO_2$, and TiO_2 in the $CaO{\cdot}SiO_2$–TiO_2 system. W.D.F.

Preparation and hydration of $CaO{\cdot}Cr_2O_3$ and $2CaO$–Cr_2O_3. Y. Sanada. *Jour. Soc. Chem. Ind. Japan*, **39** [12] 466B (1936).—$CaO{\cdot}Cr_2O_3$ is obtained at 1200°C. It crystallizes in orthorhombic crystals. $2CaO{\cdot}Cr_2O_3$ is obtained at 1350°C. It crystallizes in irregular grains. $CaO{\cdot}Cr_2O_3$ does not react with water but $2CaO{\cdot}Cr_2O_3$ reacts with water according to the following equation: $2CaO{\cdot}Cr_2O_3 + \text{water} \longrightarrow Ca(OH)_2 + CaO{\cdot}Cr_2O_3\,aq.$ M.V.C.

Reciprocal influences in the system Al_2O_3–Fe_2O_3–SiO_2–Na_2CO_3. W. A. Masel. *Legkie Metally*, **5** [6] 42–52 (1936); abstracted in *Chem. Zentr.*, **1936, ii**, 3770.—Studies of the systems Al_2O_3–SiO_2–Na_2CO_3 and Al_2O_3–SiO_2–Fe_2O_3–Na_2CO_3 at 800° and 1200° show that the disintegration of soda begins at 800°; with this is connected the formation of silicate and ferrite, while the formation of Al in silicates from sodium aluminate, ferrite, and silicate occurs at higher temperatures. The products obtained at 1200° consist chiefly of sodium aluminate, ferrite, and sodium silicate of the nepheline (carnegieite) type (whereby partly solid solutions are formed) which resist a long treatment with hot water. A formula for calculating the composition of the final product is given. M.V.C.

Rehydration of fired brick clays. L. R. Barrett. *Brit. Clayworker*, **45** [538] 350–54 (1937).—Specimens made from three materials used for building brick, fired to temperatures ranging from 705° to 1214°C, were subjected to cycles of autoclaving under water at 183°C and drying. The extent of rehydration, *i.e.*, the water which combined with the clay in the autoclave and which was irremovable by drying at 100°C at a reduced pressure of 2 mm. of mercury, was measured by weighing. Various physical measurements were made to elucidate changes in structure taking place with the autoclaving. Rehydration was greatest on materials fired below 950°. Between 950° and 1050°C, rehydration was at a minimum, and little change in physical properties took place; from 1050° to 1150°C, the fired clay was more susceptible to the action of water than at the lower firing temperatures. Above 1150°C rehydration fell off again. R.A.H.

Separation of rare earths and thorium by means of magnesium bisulfate. G. P. Alexandrov and J. P. Gochstein. *Redkie Metally*, **4** [6] 27–31 (1935); abstracted in *Chem. Zentr.*, **1936, ii**, 4200.—On the basis of experiments with synthetic salt mixtures and solutions of decomposed minerals, it is shown that oxalic acid generally used for precipitating thorium and rare earths may be replaced with good results by $MgHSO_3$. M.V.C.

Size dependency of diamagnetic susceptibility of quartz. Y. Shimizu and N. Takatori. *Science Repts. Tôhoku Imp. Univ., Series 1, Honda Anniversary Vol.*, pp. 306–11 (Oct., 1936).—Measurement of the diamagnetic susceptibility of small grains of quartz shows that it decreases markedly with decrease in size of the quartz particles. W.D.F.

Spectroscope and the atom. Alfred Fowler. *Nature*, **139** [3507] 95–98 (1937).—The topics considered are (1) the hydrogen spectrum, (2) series in other spectra, (3) multiple terms, (4) Bohr's theory, (5) ionized atoms, (6) the vector model, and (7) quantum mechanics. Spectrographs of lithium, sodium, iron arcs, and silicon are shown with the wave-lengths of principal lines indicated. J.L.G.

Spot tests for cadmium and magnesium. F. P. Dwyer. *Jour. Australian Chem. Inst.*, **4** [1] 26–34 (1937).—Paranitrodiazoaminoazobenzene (for which the name of "cadion" is suggested) is used to produce a sensitive orange-red color for Cd, and, in the presence of KCN, a cornflower-blue for Mg. H.H.S.

Thermal disintegration of F_2O. Contribution to the theory of monomolecular reactions. Hans-Joachim Schumacher. *Congr. Internat. Quim. Pura Aplicada, 9th Congress, Madrid, 1934*, **2**, 485–94; abstracted in *Chem. Zentr.*, **1936, ii**, 3754–55. M.V.C.

The 2.73μ absorption band of fused quartz. J. W. Ellis, W. K. Lyon, and D. G. Drummond. *Nature*, **139** [3506] 70 (1937).—E. and L. state that a specimen of fused silica which probably contained CO_2 did not show the 2.73μ band. Therefore CO_2 can not cause the absorption band. D. reports that a specimen which shows the 2.73μ band does not show the water-vapor bands at 1.36 and 1.87μ. This rules out water as the source of the 2.73μ band. J.L.G.

BULLETINS

Maximal tension and adsorption equilibrium. Contribution to the kinetics of heterogeneous equilibria. F. Köberich. Thesis, Berlin Univ., 40 pp., 14 illustrations; abstracted in *Referat. Silikatliteratur*, **3** [12] 3597 (1936).—A series of experiments for testing the classical and latest theories on "complete" heterogeneous equilibria is described. The systems CaO–H_2O, MgO–H_2O, $CaSO_4$–H_2O, and $3CaO{\cdot}Al_2O_3$–H_2O were studied. M.V.C.

Theoretical Metallurgy: V, Heats of Fusion of Inorganic Substances. K. K. Kelley. *U. S. Bur. Mines Bull.*, No. 393, 166 pp. Price 20¢. K. discusses heat-of-fusion values of inorganic substances from available freezing-point data of binary systems. The directly measured heat-of-fusion results are discussed in *ibid.*, Nos. 386 and 387, and several values are obtained from vapor-pressure data in *ibid.*, No. 388. The present paper discusses values derived from a wide variety of substances; they are compared, whenever possible, with results obtained by other means. For Part II see *Ceram. Abs.*, **14** [7] 170 (1935).

R. A. Heindl

PATENTS

Apparatus for producing dehydrated and crystalline anhydrous sodium tetraborate. L. G. BLACK (American Potash & Chemical Corp.). U. S. 2,073,827, March 16, 1937 (March 7, 1931). A furnace comprises a reaction chamber formed by top, bottom, and side walls and has an outlet located in the floor between the side walls and substantially continuous inlet aperture for the charging of raw material, means for forcibly introducing raw material through the aperture to form a pile of charged material covering the aperture and extending therefrom toward the outlet, and means for applying heat to the surface of the pile.

Manufacture of pyrophyllite. W. H. ALTON (R. T. Vanderbilt Co., Inc.). U. S. 2,072,063, Feb. 23, 1937 (Sept. 30, 1933). The method of purifying pyrophyllite comprises preliminarily grinding it and passing the ground material through a suitable screen such as a screen with $1^1/_4$-in. openings, returning the larger particles for further grinding, forming the finer product into a slurry, and screening it through a screen of around 15 to 20 meshes to the inch, returning the oversize particles from such screening treatment for further grinding, classifying the finer particles from such screening treatment by wet classification into finer and coarser particles, such as particles finer and coarser than about 80- or 100-mesh, passing the finer fraction in the form of a slurry on to a concentrating table of the "slimes" type, using water in the proportion of about 300 to 500 gal. per ton of material, subjecting the coarser fraction to wet-table concentration on a table of the "sand table" type with about 600 to 1000 gal. of water per ton of material, and drying the resulting purified pyrophyllite.

Method of making borides. C. W. BALKE (Ramet Corp. of America). U. S. 2,073,826, March 16, 1937 (May 28, 1934). A method of making borides comprises grinding metal and purified boron together, heating the finely divided mixture of boron and the metal while excluding the embrittling gases therefrom to combine chemically the metal and boron, and degasifying the boride thus formed in a vacuum.

Production of anhydrous boric acid. A. J. SOMER AND K. HARDING. Brit. 460,330, Feb. 10, 1937 (Oct. 9, 1935).

Purification of silica sands, etc. F. W. ADAMS (Rockware Glass Syndicate, Ltd.). U. S. 2,071,720, Feb. 23, 1937 (Sept. 1, 1934). A method for the treatment or purification of silica sands comprises treating the sand with a warm aqueous solution containing a small quantity of an alkali acid oxalate and a small amount of crystalline ferrous sulfate not exceeding one half the quantity of the acid oxalate or quadroxalate.

Treatment of silicate ores. C. DEGUIDE. Brit. 460,410, Feb. 10, 1937 (June 17, 1936).

Zirconium oxides and method of making. C. J. KINZIE AND D. S. HAKE (Titanium Alloy Mfg. Co.). U. S. 2,072,889, March 9, 1937 (March 1, 1934).

General

Ceramic material for scraper plates for mechanical sulfate furnaces. S. A. ZHIKHAREVICH AND S. D. LUKOVA. *Zhur. Priklad. Khim.*, 9 [7] 1230–46 (1936).—The ceramic material used consisted of clay and grog, with or without an addition of feldspar or quartzites. Best results were obtained with both additions used simultaneously. In plant tests, the ceramic material proved more stable than scraper plates made of acidproof cast iron. The technological conditions of the production of the material have been established. P.B. & E.S.

Developments in operation and maintenance of surface condensers. A. H. MOODY. *Combustion*, **8** [2] 19–22 (1936).—The several methods of maintaining clean condenser tubes are discussed, and the advantages of hypochlorite solution are pointed out. Practical suggestions are given for maintaining minimum air leakage; the improved performance of aluminum bronze alloy (containing 95% copper and 5% aluminum) or aluminum brass (containing 75% copper, 22.5% zinc, and 2.5% aluminum) as compared with admiralty metal for tubes is cited, and an improved method of removing condenser tubes is described. H.E.S.

Fifteen years of foundry apprenticeship at the Falk Corp. V. J. HYDAR. *Trans. Amer. Foundrymen's Assn.*, **7** [2] 321–27 (1936). H.E.S.

Geological aspects of the silicosis problem. G. W. TYRREL. *Iron & Coal Trades Rev.*, **134** [3592] 5 (1937).—Conditions which are contributive to the development of silicosis in various industries are discussed. Dusts in coal mines, sand and quartz quarries, and in potteries and clayworks in their relation to silicosis, silicatosis, and asbestosis are described according to recent investigations. M.H.

Health of cement workers: I. A. J. R. CURTIS. *Concrete* [Cement Mill Ed.], **45**, 108–109 (1937).—There is no evidence of occupational disease. The death rate is less than the average for all men in the U. S., and less than half the average for respiratory tuberculosis. All X-ray evidence is negative. Dust in itself is not harmful; overloading of the lungs is possible with ill effects, but the digestive system can also be overloaded. A positive diagnosis of silicosis must show a history of heavy exposure to pure silica dust for at least five years. Not all cases so diagnosed are silicosis and not all silicosis is disabling. **II.** *Ibid.*, pp. 123–27.—There is no silica hazard as no free silica is present in the finished cement, and the free silica present in the air-suspended dusts from the raw rock (2%) is less than the free silica content of the raw rock (6%). The size range of both raw and finished particles shows that they are usually too coarse to get into the lungs. There is no evidence of an appreciable increase in the rate of minor respiratory diseases, abdominal and digestive trouble, or in most illnesses. There has been some eye conjunctivitis among packers, which is prevented by wearing goggles; dermatitis during hot weather is prevented by the application of grease or cream. W.D.F.

Legal aspects of the silicosis problem. T. C. WATERS. *Concrete* [Cement Mill Ed.], **45**, 140–42 (1937).—Common law procedure is not satisfactory, as it is difficult to get an impartial trial, and employers have become victims of

increasingly large verdicts. The Workmen's Compensation Act first applied only to accidental injuries. Occupational diseases should be compensated under an arrangement similar to workmen's compensation but separately, because there is so much difference between them. Partial disability should be compensated. It is difficult to obtain unbiased and expert medical diagnosis of silicosis and the degree of disability. There should be a special medical board in each state for such a diagnosis. Prevention is more important than compensation and much cheaper. W.D.F.

Mineral materials which produce silicosis. B. Gossner. *Sprechsaal*, **69** [41] 601–602; [42] 616–17 (1936).—Lung diseases occurring in the porcelain industry are not produced by sericite or other minerals containing mica, as it is not present in the dust and mica is not contained by the siliceous materials used. This fact shows that lung diseases are not connected with the presence of mica. The appearance of silicosis is chiefly due to the presence of free silica in the siliceous rocks used. M.V.C.

Protection of health of glass and ceramic workers. T. Thomas. *Glashütte*, **66** [49] 825–26 (1936).—Measures to be taken in the case of various injuries sustained by workmen are discussed. M.V.C.

Rating and performance of stationary steam boilers. W. S. Patterson. *Combustion*, **8** [2] 23–30 (1936).—The absurdity of the terms "boiler horse power" and "per cent of rating" as applied to modern steam generating units is discussed, and more rational expressions are suggested. The effect of variable entering gas temperature, operating pressure, and superheat on the boiler performance is analyzed and illustrated by curves and equations. Gas-temperature gradient and draft loss through boilers are also discussed. H.E.S.

Report of the Committee on Ceramic Education for 1936. Harold E. White. *Bull. Amer. Ceram. Soc.*, **16** [3] 111–20 (1937).—This report includes tabular data compiled by E. E. Marbaker and E. H. Fritz.

Suggestions for starting and maintaining a foundry apprenticeship system. J. E. Goss. *Trans. Amer. Foundrymen's Assn.*, **7** [2] 328–50 (1936).—G. outlines points to be taken into consideration in apprentice training, such as methods of selection, testing prospects, age limits, rates of pay, piece work, requirements of a program, necessity of centralized activities, trial apprenticeship periods, agreements, kind of instruction, related work, etc. A discussion is included. H.E.S.

BOOKS AND BULLETINS

Bureau of Mines activities in the field of building materials. D. M. Banks. *U. S. Bur. Mines Information Circ.*, No. 6924, 51 pp. Free. B. collates all publications by members of the Bureau personnel on the subject of building materials and includes reports published by the Government Printing Office and mimeographed by the Bureau and articles in technical journals and coöperative reports. R. A. Heindl

Chemist's Year Book. Edited by E. Hope. Sherratt & Hughes, Manchester; Chemical Publishing Co., New York, 1936. 18th ed. Price $6.00. 1257 pp. The handbook has complete information concerning the various chemical constants and characteristics and properties of most organic and inorganic elements and compounds. In addition, various qualitative and quantitative determination procedures are given both for organic and inorganic substances. M.C.Shaw

National Physical Laboratory Collected Researches: Vol. XXV, 1935. H. M. Stationery Office, London. 432 pp. Price £1 5s. The volume contains twenty-three reports of researches devoted chiefly to the study of metallurgical problems. The reports cover studies of the various iron alloys, alloys of Au-Cu, Cd-Zn, Ag-Sn, and Ag-Hg, metallic cadmium, and the crystal structure of α- and β-manganese. One paper is devoted to special refractories for metallurgical research. A brief résumé is given of the properties and methods of producing refractory crucibles, muffles, and tubes from silica, alumina, magnesia, thoria, alumina-clay, and silicon carbide-clay. M.C.Shaw

Official Year-Book of the Scientific and Learned Societies of Great Britain and Ireland; Record of Publications Issued during the Session 1935–1936. Compiled from Official Sources. 53rd annual issue. Charles Griffin and Co., Ltd., London, 1936. vii + 170 pp. Price 10s net. Noted in *Nature*, **139** [3506] 51 (1937). J.L.G.

Third Ordinance Increasing Compensation of Occupational Diseases in Germany. M. Bauer. Reprint from *Reichsarbeitsblatt*, No. 36, Part IV (1936). 47 pp. Berlin, 1937. The new ordinance relating to occupational diseases in Germany went into effect April 1, 1936, superseding the Second Ordinance of Feb. 11, 1929. Several industries are added to the list of compensable diseases, including all the ceramic industries (previously only the porcelain industry was insured), sandblasting, and operations for cleaning castings and molds. Asbestosis in the asbestos trades and lung cancer in the chromium industries become compensable. Severe silicosis, compensable under the Second Ordinance, is still the only form of silicosis insured against, but what constitutes the disease for clinical, röntgenological, and judicial estimation is definitely specified, thus doing away with a hitherto vexatious miscellany of complications. Severe silicosis accompanied by pulmonary tuberculosis requires only the establishment of the severe silicosis in diagnosis. Among damage claims reported for occupational diseases since 1929, silicosis has stood at the peak; in 1934, of 1043 cases, 522 were for silicosis; in 1935, of 1161 cases, 627 were for silicosis, with 146 deaths in 1935 from this cause. K.R.

NEW JOURNAL

Staub (Dust). Edited by C. Lämmert. Vol. 1, No. 1, April, 1936. Published quarterly by Wilhelm Knapp, Halle. Price 5 Rm. The Association of German Industrial Insurance Societies reports on the current status of the dust-control compaign and surveys the literature. Two or three original research papers comprise the first part of each issue, followed by reviews of pertinent literature arranged systematically under (1) dust research into properties, estimation, and measurement, (2) dust sources, (3) dust diseases, (4) other dust injuries, (5) preventive methods, and (6) laws and decisions. K.R.

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